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PROGNOSIS AND TREATMENT OF FRACTURES OF THE FEMUR

REPORT OF ONE HUNDRED AND ELEVEN CASES *

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Ten years have elapsed since the Committee on Fractures of the American Surgical Association presented their comprehensive report, which included an analysis of 829 cases of simple fractures of the long bones, 453 of which were fractures of the femur. These case reports were collected from fellows of the association and from other surgeons throughout this country and Canada; so the figures may be held to have represented the average results at that time.

Following the policy mentioned in a former paper,[1] to ascertain our own end-results, the investigation reported here has been made of patients with fracture of the femur, most of whom have been under our care during the last ten years. Out of 111 such patients (up to Oct. 1, 1924), thirteen died during treatment.[2] The general mortality of patients with fractures of the femur in civil life may thus be reckoned as about 12 per cent.[3]

Of the ninety-eight patients who survived their injuries, eighty-seven, or 89 per cent., have been traced.

During the same period the following cases of pathologic fracture of the femur were encountered. These cases are not included in the present study.

1. Woman, 69 years. Dec. 30, 1916. Shaft, from Paget's disease. Union.

2. Woman, 59 years. Nov. 3, 1921. Shaft, from metastatic malignant tumor. Amputation at hip; death one year later from patient's disease.

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* From the Episcopal Hospital.

* Read at meeting of the American Surgical Association, Washington, D. C., May 4, 1925.

1. Ashhurst, A. P. C., and Crossan, E. T.: Prognosis and Treatment of Fractures of the Leg and Ankle, Tr. Am. S. A. **41**:594, 1923.

2. We have omitted from these deaths two other patients who died from fracture of the skull sustained simultaneously with simple fractures of the femur.

3. In a series of 121 patients with fractures of the femur treated in the Episcopal Hospital prior to 1908, the mortality was 18 per cent. (Ashhurst and Newell: The Conservative Treatment of Fractures of the Femur, Ann. Surg. **2**:748, 1908).

3. Man, 64 years. Aug. 29, 1922. Shaft, from metastasis from carcinoma of prostate (found only at necropsy). Amputation at hip, death five weeks later from carcinoma.

4. Woman, 49 years. Oct. 10, 1922. Shaft, from cystic osteitis. Fibrous union with deformity.

5. Girl, 6 years. Jan. 15, 1923. Shaft, from rachitis. Union.

6. Man, 65 years. Oct. 2, 1923. Shaft, from Paget's disease. Union with deformity.

7. Boy, 16 years. Oct. 28, 1923. Shaft, from osteomyelitis. Union.

8. Woman, 48 years. February, 1924. Shaft, from osteomalacia. Nonunion.

TABLE 1.—*Fractures of Femur*

Site	Cases	Recovered (89%)	Traced (89 %)
Neck	16	14	12
Trochanters	33	26	22
Below trochanters	10	9	7
Shaft	41	40	39
Condyles	11	9	7
	111	98	87

Among these 111 cases were three instances of fracture of both femurs simultaneously: (1) a boy, aged 18 (1914), with a simple fracture of both femurs below the trochanters; recovery with good anatomy and good function; (2) a man, aged 34 (1908), with a simple fracture of the right internal condyle into the knee joint, with partial dislocation of the knee, and with a compound fracture of the shaft of the left femur; recovery with good anatomy and moderate function,[4] and (3) a man, aged 59 (1914), with compound fracture of the shaft of the right femur and simple fracture of the shaft of the left femur; recovery with bad anatomy and moderate function.

With the exception of three patients among those with intracapsular fracture of the neck of the femur, every patient who survived secured bony union. One patient, convalescent from a compound fracture of the shaft, refractured his femur while walking about the hospital ward.

Two patients developed peroneal palsy either from constriction of the adhesive plaster used for extension, or from direct splint pressure: in one case function was fully recovered within six weeks; but in the other only slight improvement was noted during the five months that the patient was under observation after the lesion was first observed.

In the entire series of eighty-seven patients, there were only ten who recovered with limitation of flexion in the knee joint, and in only three of these ten was flexion to a right angle or further impossible.

4. This case was reported in detail in Ann. Surg. **2**:648, 1909.

The tables accompanying this report are compiled in accordance with the plan of the Fracture Committee of the American Surgical Association, and we believe it is worth while again to call attention to the definitions of that report: "The *anatomical result* denotes the position assumed by the fragments of bone at the time of consolidation." In children, especially, a bad anatomic result in this sense may eventually prove to be a very good anatomic result; but in strict accord with our definition we have counted no anatomic result good unless at the time of consolidation there was present accurate anatomic reposi-

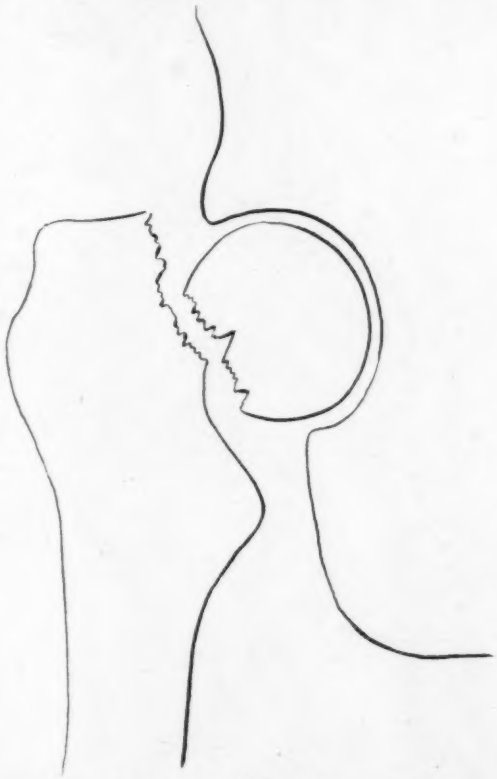

Fig. 1.—Fracture through neck of femur (intracapsular) on admission in 1913: treated by longitudinal and lateral traction; treatment complicated by development of delirium tremens and later by acute cholecystitis; patient was out of work eight months.

tion of the fragments. If such absolute anatomic reposition was not secured, the anatomic result has been recorded as "moderate," even if eventually the bone ends became rounded off so that no palpable deformity remained. Any gross anatomic deformity or any appreciable shortening (over 2 cm.) has been classed as a bad anatomic result (Table 5).

So also with regard to functional results, we have followed the Fracture Committee's criterion that a good functional result implies the absence of any disability whatever. If there is pain in damp weather, if the patient tires more easily, if swelling occurs, or if there

Fig. 2.—Femur shown in Figure 1 twelve years later; the patient, a woman, aged 58, did housework, making normal wages; she had a slight limp and felt some pain after a hard day's work; the shortening was 4 cm. and there was limited motion; bad anatomic but moderate functional result.

is any limp, we have classed the functional result as moderate only, even if the patient has resumed his normal occupation and makes the same wages. Any real incapacity interfering with work has been classed as a bad functional result. As most fractures about the hip

occur in elderly patients, it is scarcely to be expected that good functional results in the foregoing sense will be found in patients with a fracture of the femur at such a site.

CLASSIFICATION

Fractures of the femur are conveniently grouped as follows:

1. Fractures through the neck, which are mostly or entirely intracapsular (Figs. 1 and 2).

2. Fractures through the trochanters, which include three subvarieties:[5]

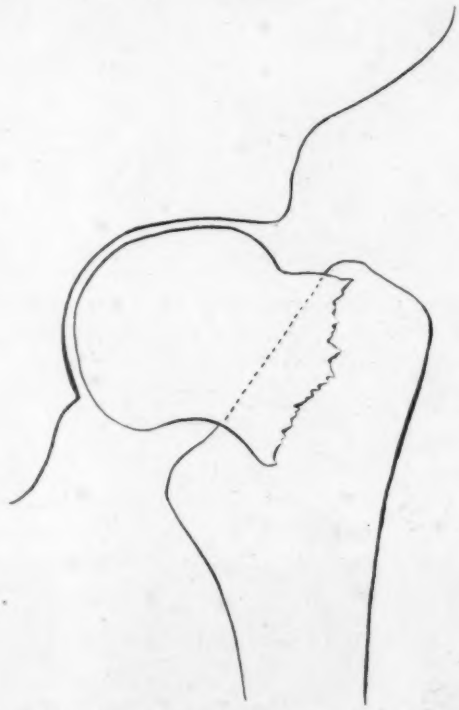

Fig. 3.—Impacted fracture at base of neck of femur (extracapsular).

(*a*) Fractures at the base of the neck, which are wholly or largely extracapsular and usually impacted (Fig. 3).

(*b*) Fractures causing partial comminution of the great trochanter (Fig. 4), and which in their least serious form are simply a more advanced grade of fractures at the base of the neck while in their more serious forms they verge into Type *c*.

(*c*) Fractures involving both trochanters, usually with some comminution (Fig. 5).

5. Ashhurst, A. P. C.: Fractures Through the Trochanters of the Femur, Ann. Surg. **2**:494, 1913.

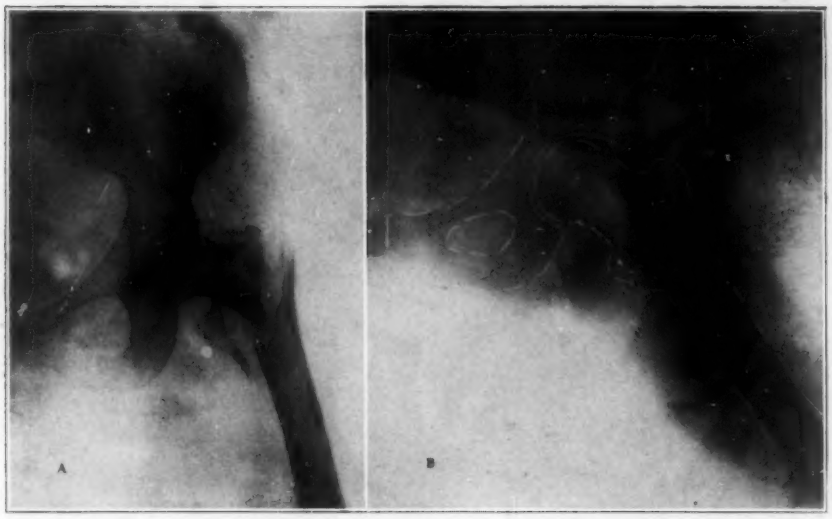

Fig. 4.—*A*, fracture through trochanters of femur in woman, aged 61; *B*, after reduction and retention in abduction cast; patient was out of work nine months; good anatomic and functional result.

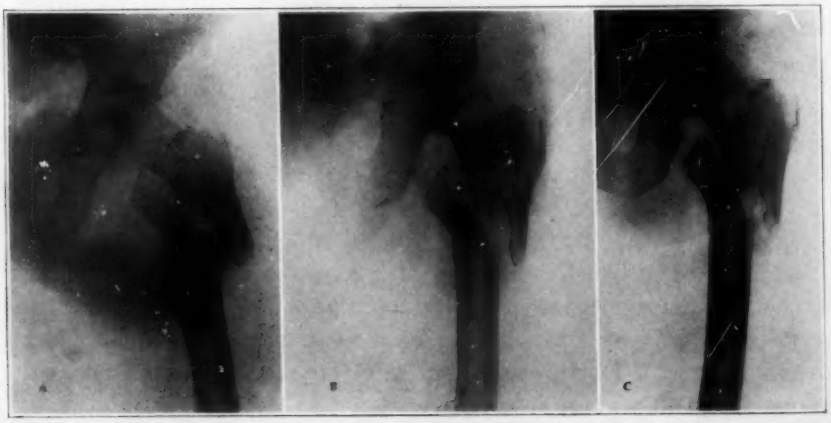

Fig. 5.—*A*, fracture through trochanters of femur in man aged 43; *B*, after gradual reduction by longitudinal traction by Buck's extension apparatus; *C*, two months after injury: the patient was walking on crutches and the knee flexed to a right angle.

All these "fractures through the trochanters" give much the same prognosis as to function, and for practical purposes need not be distinguished.

3. Fractures just below the trochanters.

4. Fractures of the shaft.

5. Fractures involving (indirectly or directly) the knee joint:

(*a*) Fractures just above the condyles (within 10 cm. of the joint surfaces).

(*b*) Fractures of one or both condyles.

TABLE 2.—*Mortality in One Hundred and Eleven Cases of Fracture of the Femur*

Site	Total Cases	Recovery	Died	Simple	Recovery	Died	Compound	Recovery	Died
Neck (intracapsular)	16	14	2	16	14	2	..	..	..
Trochanters	33	26	7	33	26	7	..	..	..
Below trochanters	10	9	1	10	9	1	..	..	..
Shaft	41	40	1	36	36	0	5	4	1*
Condyles	11	9	2	7	6	1†	4	3‡	1
	111	98	13	102	91	11	9	7	2

* Gunshot fracture; death in few hours from shock.
† Death in two months from senility.
‡ Two of these patients recovered only after amputation.

TABLE 3.—*Analysis of Trochanteric Fractures (None Compound)*

	Total Cases	Recovery	Died
(*a*) Base of neck	9	8	1
(*b*) Comminution of trochanters	24	18	6

TABLE 4.—*Analysis of Fractures of Condyles*

	Total Cases	Recovery	Died	Simple	Recovery	Died	Compound	Recovery	Died
(*a*) Supracondylar	6	5	1	4	3	1	2	2	0
(*b*) Into knee joint (one or both condyles)	5	4	1	3	3	0	2	1	1
	11	9	2	7	6	1	4	3	1

Fractures of the femur are rarely compound in civil surgery: those involving the knee joint most frequently (33 per cent. of cases); then those of the shaft (12 per cent.), while those of the trochanters and neck are scarcely ever compound.

TRANSPORTATION

It has been noted that patients who have been transported in our own ambulance, with transport splints properly applied, rarely present, on admission to the hospital, great displacement of the fragments. This

suggests that the displacement seen in other cases has developed during transportation to the hospital, and is not the result of the original accident. When first reached by the ambulance surgeon, a hypodermic injection of morphin is given if the patient is shocked or in much pain. Then the surgeon is instructed to inspect the site of fracture, cutting away clothing if necessary, before applying the splint. If a wound of the soft parts is found, it is swabbed with 3.5 per cent. alcoholic solution of iodin, and when this has dried the wound is covered with sterile gauze. Even if no wound is found, inspection of the site of fracture is indicated, because a fragment of bone may be threatening to perforate the skin; such a complication may be preventable by a little judicious manipulation and traction during the application of the transport splint. No formal attempt is made at reduction.

The Keller half-ring modification of the Thomas knee splint is habitually employed by us. It is applied to the patient at his home or at the place of accident before he is placed on the stretcher and carried

TABLE 5.—*End-Results in Eighty-Seven Cases of Fracture of the Femur*

		Functional		
Anatomic		Good	Moderate	Bad
Good	44 (50%)	34 (77%)	9 (21%)	1 (2%)
Moderate	34 (40%)	15 (44%)	14 (41%)	5 (14%)
Bad	9 (10%)	6 (66%)	3 (33%)	0
Total	87 (100%)	55 (63%)	26 (30%)	6 (7%)

to the ambulance. The slings are tightened beneath the thigh and leg, and a felt lined anklet is bandaged to the foot and fastened to the notch in the lower end of the splint. Traction is then made by twisting the traction straps like a "Spanish windlass" until the padded ring of the splint presses upward against the tuberosity of the ischium; then the strap across the front of the hip is tightened and the patient is ready for transport. A wire pedestal to steady the splint on the stretcher and a support to prevent foot-drop add much to the patient's comfort.

On arrival at the hospital, a roentgen-ray examination is made without removal of the transport splint. In some cases of trochanteric fracture, the ischial ring may obscure the line of fracture, especially if there is no displacement. After roentgen-ray examination, preparations are made for application of permanent dressings. Subsequent roentgen-ray examinations are made as often as seems indicated: this is at least (*a*) after application of permanent dressing; (*b*) again when commencing union is expected, and (*c*) just before the patient's discharge.

Only in fractures through the neck of the femur and in those just above or involving the condyles have special efforts been made to secure "anatomic reposition" of the fragments. In fractures not compromising

directly the motions of the hip or knee joints, we have been satisfied to secure union without shortening and without rotatory or angular displacement, even if actual end-to-end reduction was absent. Only when these desiderata seemed unattainable without it was resort made to operation.

FRACTURES THROUGH THE NECK OF THE FEMUR

Fractures through the neck of the femur are comparatively rare. In the present series of 111 cases, only sixteen were of this type: twelve in females and four in males. On the day of admission the patient, unless very feeble or in marked shock, is anesthetized (gas and oxygen), and an abduction cast (Whitman, 1897) is applied.

The few patients in whom this treatment seems unjustifiable are treated either by longitudinal traction alone (by means of Buck's extension apparatus) in a position of moderate abduction, or by combined longitudinal and lateral traction, as originally advocated by Phillips in 1869, and as later (1899) popularized by Ruth, and now sometimes called the Maxwell-Ruth method. This method of treatment will be more particularly described when speaking of fractures at the base of the neck and trochanteric fractures.

In the use of the abduction cast, after overcoming shortening by longitudinal traction and fixing the pelvis by full abduction of the other limb, we have been satisfied to abduct the fractured hip gently but persistently until (in most cases) a crunching sound is heard, indicating that a certain amount of impaction has occurred. In no case have we employed the mallet as used by Cotton to secure impaction. The cast extends high on the side of the chest opposite the fracture, to prevent adduction; it does not extend down on the normal thigh. The hip and knee are slightly flexed, and the hip is rotated in, slightly, before the plaster is applied. It is important to cover in all of the buttock, to prevent sagging of the pelvis. We have found this abduction cast very efficient in all but immensely fat patients. The nurses find it much easier to prevent the development of bed sores or to secure their healing if once formed, than is the case with other forms of apparatus in which the patients cannot be turned daily or oftener on the abdomen. The head of the bed is kept elevated, enabling the patient to see around the ward, and lessening the chance of pulmonary congestion. Several of our patients in this apparatus have successfully weathered attacks of hypostatic pneumonia, which might have been fatal unless the patients could have been turned face downward at frequent intervals.

The abduction cast is removed gradually after the tenth or twelfth week: beginning with removal of the cast from the foot and then from

the waist, the hip is not entirely freed from restraint until ten days or two weeks later. Ther the patient is allowed to lie in bed several weeks longer while massage is employed, and only after the patient has regained ability to move around easily in bed is he allowed up in a wheel chair. When this is well borne, walking with crutches is allowed; but full weight is not borne on the fractured hip for at least six months after injury. When union seems weak, a caliper brace is provided before walking is allowed at all, so that the patient transfers most of the weight from the foot directly to a padded ring beneath the tuberosity of the ischium.

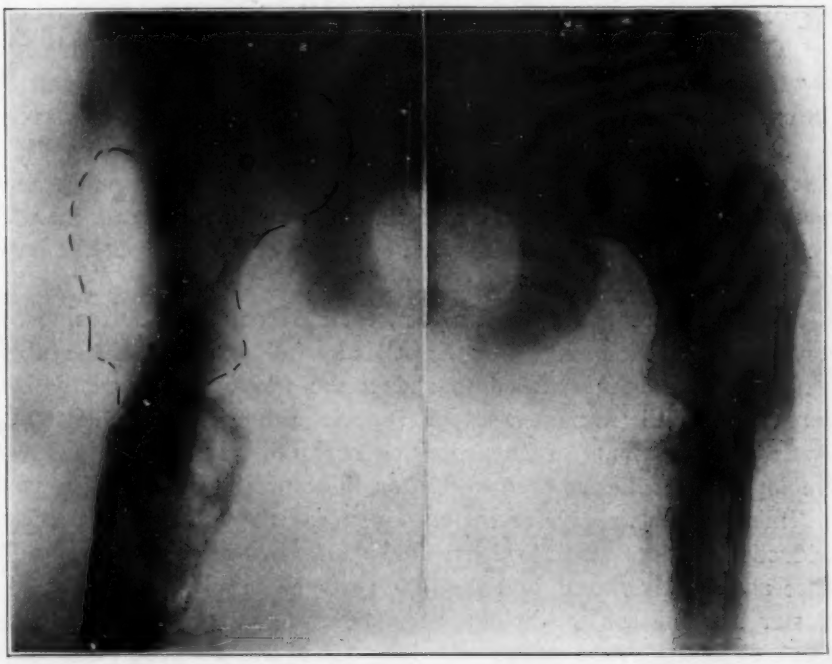

Fig. 6.—Fracture below trochanters of both femurs in man, aged 18, treated by Buck's extension apparatus in slight flexion and abduction; the patient was out of work about four months; good anatomic and functional result.

Our results in these intracapsular fractures of the neck of the femur have not been brilliant. There were two deaths among sixteen patients. The ages of those who died were: (1) 54 years (death in two weeks from uremia and delirium); (2) 80 years (death in three months from senility). The average age of all sixteen patients was 52 years. The average age of the survivors was 50 years, varying from 4 to 87 years. If the two children (ages 4 and 14 years) are omitted, the average age of the survivors is nearly 57 years. Of the surviving fourteen patients, the end-result is known in twelve: two of the sur-

vivors (ages 81 and 87 years) were permanently disabled. The average period of disability in the remaining eight adult patients was almost ten months. Of these eight adult patients, three recovered with good anatomic results, four with moderate anatomic results, and one with a *bad* anatomic result. Seven had moderate function, and only one had a

Fig. 7.—Fracture through neck of femur (intracapsular) in man, aged 20, with flail hip, knee and ankle from infantile paralysis.

bad functional result, which was due to nonunion. It is certainly a more serious injury than many recent reports, which mention no deaths, would lead one to believe. With the exception of two cases, one a child of 4 years and the other a boy of 14, both with epiphyseal separation of the head, no patient has recovered with entire absence of dis-

ability. The only complaint made by the boy of 14 years was that he could no longer vault over a fence with the injured leg first.

Even the best result in an adult (Fig. 9) has left the patient with a hip of which she is conscious after long walking, and which limits (if even only to a slight degree) her activities. Only in one instance does the patient consider his state after the accident better than before, and

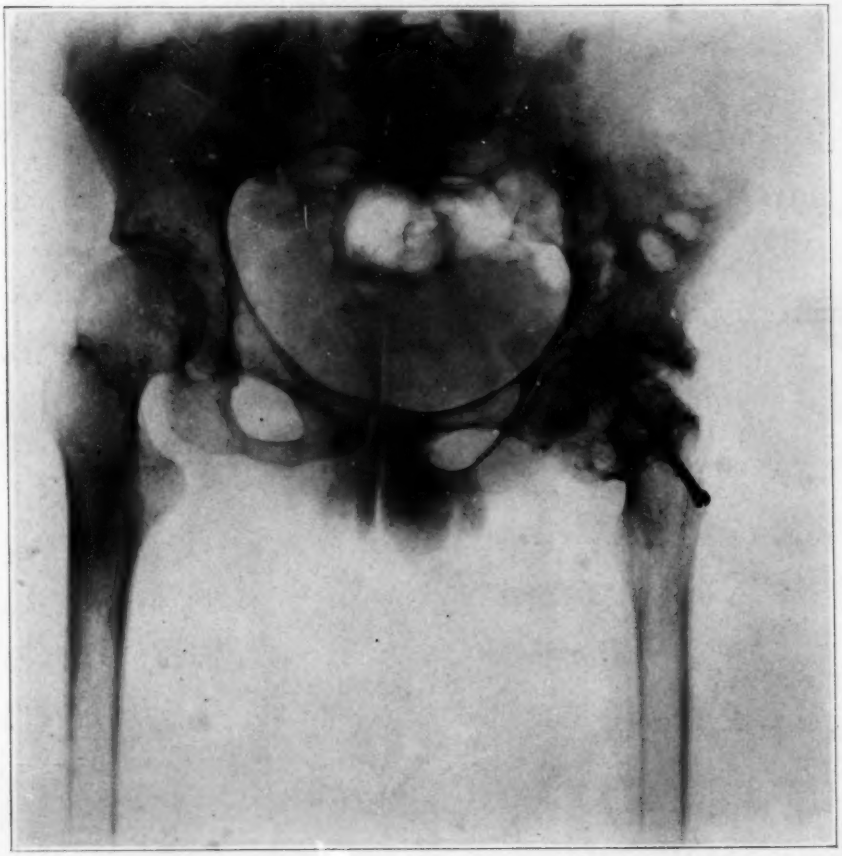

Fig. 8.—Fracture shown in Figure 7 three years later: open reduction and screw fixation; good anatomic result; slight bending of screw; function much improved by operation but hip motion less than half normal.

this case is scarcely a fair test, as the young man (aged 20) was already almost incapacitated from infantile paralysis of both lower limbs and could walk only with the aid of braces and a cane: after sustaining an intracapsular fracture of the left hip (this limb having been utterly flail at hip, knee and foot), he found his locomotion much improved

by the relative stability secured by screw fixation of the fragments; so that now he is able to dispense with his cane except for long walks (Figs. 7 and 8).

Nine patients out of twelve who were traced secured bony union after intracapsular fracture of the neck of the femur. They were (1) a

Fig. 9.—Fracture through neck of femur (intracapsular) in woman, aged 41: treated in abduction cast; the patient was out of work ten months, then resumed same job at same salary; pain after much exertion persisted ten years after injury; good anatomic, moderate functional result. A skiagraph was made at the time of discharge from the hospital.

child aged 4 years and (2) a boy of 14 years, both with epiphyseal separations of the head; (3) the young man with paralytic limbs just mentioned; (4) a woman aged 41; (5) a woman aged 49; (6) a

woman aged 46; (7) a woman aged 53; (8) a woman aged 87, with an impacted fracture through the neck, and (9) a woman aged 75. In seven of these nine cases, the abduction cast was employed. The sixth patient noted above was treated in 1913 by longitudinal and lateral traction, and twelve years later a skiagraph showed bony union but considerable displacement; there is 4 cm. shortening but the woman does the same work and receives the same or better wages (Figs. 1 and 2).[6] The eighth patient listed above, with impacted fracture through the neck, was already an inmate of an incurable ward; she was treated merely by support by sand bags but survived her injury more than five years, with bony union, though confined to her chair by age (92 years) and infirmities.

TABLE 6.—*Fractures Through the Neck (Intracapsular)*

Anatomic Result	Cases	Function		
		Good	Moderate	Bad
Good	6	2	4	0
Moderate	5	0	2	3
Bad	1	0	1	0
	12	2*	7†	3‡

* Children 4 and 14 years of age; no disability.

† All adults; four able to resume their former work; three handicapped and make less wages or have retired.

‡ Only one patient was of working age; incapacitated by nonunion.

In addition to the seven patients noted above who secured bony union after treatment in an abduction cast, the same method of treatment was used in three other cases in which nonunion or fibrous union resulted.

The general results in our series of cases of intracapsular fractures are seen in Table 6.

Eighteen years ago Scudder[7] reported the end-results of sixteen "fractures of the neck of the femur": only two patients had functionally useful limbs. Walker[8] about the same time found that among fifty-two patients with "fracture of the neck of the femur" no less than thirty, 57.6 per cent., were incapacitated, twelve were still compelled to use a cane, and only ten (less than one out of five) could do their normal work. It is not clear whether these figures of Scudder and Walker include only intracapsular fractures, as in the present series,

6. This case was reported in some detail as Case 1 by Ashhurst (Footnote 5).
7. Scudder: Treatment of Fractures, Ed. 6, Philadelphia, 1907, p. 336.
8. Walker, J. B.: Ann. Surg. **1**:84, 1908.

or fractures at the base of the neck also. Among twenty-one fractures of the neck of the femur (including intracapsular and extracapsular forms) reported from the Episcopal Hospital in 1908,[9] five patients had no disability at all, and eight had no disability except a limp; six had marked impairment of function, and two were incapacitated. The report of the Fracture Committee of the American Surgical Association (1915) also included fractures through the neck (intracapsular) and fractures at the base of the neck (extracapsular) under the same heading. These figures covered sixty-nine cases, seventeen, or 25 per cent., of which were classed as good functional results, thirty-one, or 45 per cent., as moderate, and twenty-one, or 30 per cent., as bad functional results.

If the results noted were representative of the treatment of all varieties of "fractures of the hip" ten or fifteen years ago, it is gratifying to learn that seven out of eight adult patients of working age (treated since that time for wholly intracapsular fractures) recovered without disabling infirmities, even if only four out of the seven were able to resume their former work, being hampered only by a little less endurance, pain after long standing, or some stiffness of the hip.

It is perhaps pertinent to remark that in some recent series of cases reported in the current journals under the title of "intracapsular fractures of the hip," opportunity was offered those who were present at the meetings where these articles were read, to examine the skiagraphs; most of these, of course, could not be published with the papers. In the cases in which we ourselves enjoyed this privilege, we became convinced that many of the cases reported as intracapsular fractures were in reality fractures at the base of the neck, and not through the neck. This inaccuracy is to be regretted, as it has given rise to a false impression of the results obtainable in cases in which the fracture is truly intracapsular. Moreover, the reporters have used the term "good result" in a much more elastic and comprehensive sense than is implied by the definition already quoted on the authority of the Fracture Committee of the American Surgical Association.

FRACTURES THROUGH THE TROCHANTERS OF THE FEMUR

There were thirty-three patients in the group of fractures through the trochanters of the femur (twelve males, twenty-one females) with an average age of 64.3 years. Seven of these patients died while under treatment, a mortality of over 21 per cent. Of these thirty-three

9. Ashhurst, A. P. C., and Newell: The Conservative Treatment of Fractures of the Femur, Ann. Surg. **2**:748, 1908.

patients ten had what we class as a fracture at the base of the neck, while twenty-three had more or less comminution of the trochanteric region. The deaths were as follows:

1. Woman (Coles), aged, 72, death on eighteenth day from pulmonary (fat?) embolism or rapid heart failure.

2. Man (Fees), aged 65, death after one month from uremia.

3. Woman (Humphries), aged 67, admitted four days after injury; death four weeks later from bedsore and sepsis.

4. Man (Klaiss), aged 70, death on fourth day from gradual heart failure.

5. Woman (Huttenlock), aged 70, death after three months from senile dementia.

6. Woman (Thompson), aged 88, death after two months from suppurative parotitis.

7. Woman (Wardell), aged 72, death on eleventh day from shock and exhaustion.

(*a*) *Fractures at the Base of the Neck (Fig. 3).*—In this group were ten patients, four male, six female, with an average age of 65.6 years, with one death (Patient 4): two of these patients were treated in abduction casts, good function being secured in both cases; six were treated by longitudinal and lateral traction, good function being secured in one, moderate in three, bad in one (this patient, aged 86) and one not being traced; and two were treated by longitudinal traction alone, good function resulting in one, death in one.

In all cases treated by weight extension, some form of sliding foot splint is applied, according to Volkmann's principle, to diminish the friction of the limb on the bed and to prevent outward rotation. At the same time the foot of the bed is raised from 20 to 25 cm. to provide countertraction; if lateral traction also is employed, the side of the bed on the injured side is raised a little also. Enough longitudinal traction is employed to overcome shortening, and about two-thirds as much weight in lateral traction. The longitudinal traction is applied in the usual manner, the adhesive strips extending up to midthigh. The lateral traction is applied to the adductor region as high as possible (over a felt or padded binder's board splint) and the pull should be somewhat toward the head of the patient's bed as well as upward from the surface of the bed: this oblique traction tends to keep the shaft fragment (including of course the trochanters) from sagging and rotating outward, bringing the fractured surfaces into nearer apposition. The patients may sit up on a bed rest, as the lateral traction keeps them from sliding down toward the foot of the bed. After eight or ten weeks the lateral, and then the longitudinal, traction is gradually diminished and finally removed.

(*b*) and (*c*) *Comminuted Fractures Through the Trochanters.*—In this group were twenty-three cases (eight male, fifteen female), the

average age being 63.7 years, with six deaths. This high mortality is due partly to the fact that the injury usually is a more severe one than an intracapsular fracture or a fracture at the base of the neck, and partly to the age of the patients, the average age of those who died being 73 years (from 65 to 88 years), while in the patients who recovered the age varied from 32 to 82 years, with an average of 59 years.

TABLE 7.—*Fractures at Base of Neck (Extracapsular) in Eight Patients Traced Out of Nine Surviving*

		Function		
Anatomy		Good	Moderate	Bad
Good	3	3	0	0
Moderate	5	1	3	1
Bad	0	0	0	0
Total	8	4	3	1

TABLE 8.—*Comminuted Fractures Through Trochanters in Fourteen Patients Traced Out of Eighteen Surviving*

		Function		
Anatomic Result		Good	Moderate	Bad
Good	9	5	3	1
Moderate	4	1	3	1
Bad	1	0	1	0
Total	14	6	6	2

TABLE 9.—*Fractures in Region of Trochanters in Twenty-Two Patients Traced Out of Twenty-Six Survivors*

		Function		
Anatomic Result		Good	Moderate	Bad
Good	12	8	3	1
Moderate	9	2	5	2
Bad	1	0	1	0
Total	22	10	9	3

Six of these patients were treated in abduction casts, with two deaths, two good and two bad functional results. The end-results are known in fourteen patients treated by Buck's extension apparatus; longitudinal traction was employed in all, and in some cases lateral traction also: four patients died under treatment, and of the ten surviving and traced patients four recovered good function and six moderate function; there were no bad functional results in patients so treated. Figure 4 shows a form of fracture through the trochanters

suitable for reduction and retention by means of an abduction cast. Figure 5 shows a deformity usually well overcome by simple longitudinal traction by means of Buck's extension apparatus.

Our experience with twenty-two traced cases of fractures in the region of the trochanters (impacted fractures at the base of the neck and more or less comminuted fractures involving both trochanters), is summarized in Table 9.

Among these twenty-five patients treated in the abduction cast there occurred five deaths, 20 per cent. This mortality is to be compared with that of nine deaths among forty-nine patients (about 18 per cent.) in the entire group of neck and trochanter fractures, and with four deaths among twenty-eight patients (about 14 per cent.) treated by means other than the abduction cast. This raises the question whether the use of the abduction cast was responsible for the increased mortality, and whether some of the patients so treated might have survived if treated by other

TABLE 10.—*Cases of Neck and Trochanters Treated in Abduction Cast in Twenty-Five Patients* *

Anatomic Result		Function		
		Good	Moderate	Bad
Good	10	5	4	1
Moderate	6	1	2	3
Bad	0	0	0	0
Total	16	6	6	4

* Four patients not traced, five deaths.

means. We do not believe the patients who died would have survived any longer under any form of treatment; the reader may judge for himself from the following summary of these deaths:

1. Patient, aged 80; from "senility" three months after reduction under gas.
2. Patient, aged 72; from embolism eighteen days after reduction under gas.
3. Patient, aged 65; from uremia one month after reduction without anesthetic.
4. Patient, aged 88; from parotitis two months after reduction under gas.
5. Patient, aged 72; from "shock and exhaustion" eleven days after reduction under gas.

FRACTURES BELOW THE TROCHANTERS

Fractures below the trochanters are rare, if, as we have done, those are excluded which involve both trochanters (Figs. 4 and 5). Only ten strictly subtrochanteric fractures (Fig. 6) are in our series of 111 cases. One death from hypostatic pneumonia occurred in a woman, aged 75, one month after the accident. This patient had been treated in suspension, abduction and flexion of the hip. Unless there is great flexion of the upper fragment or its entanglement in the muscles, or the fragments of an oblique fracture are transposed (i. e., with their

periosteal surfaces back-to-back and their fractured surfaces not facing each other), we have found that these fractures may be treated with satisfaction by means of Buck's extension apparatus, the limb being in moderate abduction and flexed only as far as required by the sliding leg splint which is used in all cases with Buck's extension. The adhesive plaster for traction should extend up almost to the groin.

During the first twenty-four hours after the injury, sufficient weight should be added gradually to overcome the shortening. If friction is eliminated, as it may be very largely by use of a sliding foot splint (modeled after that introduced by Volkmann in 1882), much less weight is required to overcome shortening than when the limb lies flat on the bed; and if the maximum weight is employed during the first day or two it is much more efficient than a much greater weight applied after organization of the effused blood has commenced. It is true that, during the first six or twelve hours after the application of

TABLE 11.—*Fractures Below the Trochanters (Seven Patients Traced Out of Nine Surviving)*

Anatomic Result		Function		
		Good	Moderate	Bad
Good	4	4	0	0
Moderate	2	1	1	0
Bad	1	1	0	0
Total	7	6	1	0

the Buck extension apparatus, too great traction may pull off the adhesive plaster; but when the plaster has once become warmed up and has set to the limb, it will stand a very heavy weight. We have not found it necessary to employ more than 24 pounds in any case, and in most cases from 15 to 18 pounds is sufficient. Not more than 2 cm. shortening is permissible if the patient is to recover without any disability. No shortening at all is of course preferable; but if traction of 20 pounds or more fails to reduce the shortening to less than 2 cm. in the course of two or three days, we believe the surgeon may as well rest satisfied. Though the anatomic result will not be perfect, function may be, and indeed usually is. The question of operation is discussed later.

Our results are shown in Table 11.

FRACTURES THROUGH THE SHAFT OF THE FEMUR

Fractures through the shaft of the femur (excluding subtrochanteric and supracondylar types) comprise the greater proportion of injuries: forty-one out of the 111 cases in our series. But in adults the injury is much less frequent than in children, sixteen occurring in adults (four-

teen men, two women), and twenty-five in children under 15 years (eighteen boys, seven girls). The results in forty traced cases are as follows: one death (compound comminuted gunshot fracture, death in a few hours from shock); thirty-five with good function, four with only moderate function, and none with bad function. Thirty-six of these fractures were simple, and only five were compound.

Only four patients did not secure a perfect functional result. They made the following complaints:

1. A very fat woman, aged 38, after four years still had some pain in damp weather, limped when tired, and had 20 degrees less flexion in the knee than on the normal side. She worked at the same job and wages.

TABLE 12.—*Shaft of Femur: Results in Thirty-Nine Cases*

Anatomic Result		Function		
		Good	Moderate	Bad
Children Under 15 Years—				
Good	11	11	0	0
Moderate	9	9	0	0
Bad	4	4	0	0
Total	24	24 (100%)	0	0
Adults—				
Good	9	8	1	0
Moderate	5	2	3	0
Bad	1	1	0	0
Total	15	11 (73%)	4	0
All Cases—				
Good	20	19	1	0
Moderate	14	11	3	0
Bad	5	5	0	0
Total	39	35 (90%)	4 (10%)	0

2. A hard drinking man, aged 59, with fracture of both femurs, compound of one, has pain in damp weather and lessened endurance. He was out of work six months, but retained his job and wages.

3. A man, aged 26, with fracture of both femurs, one elbow and both jaws, complained of interference with full flexion of one knee, and could not resume his previous job of climbing telegraph poles.

4. A man, aged 23, refractured the femur after walking about the ward for eight days. He complains that the knee flexes only to 90 degrees. He retains the same job and wages.

In adults much the same dressings have been employed as those described in connection with trochanteric and subtrochanteric fractures, but usually with the addition of coaptation splints to the thigh. The adhesive plaster of the extension apparatus should be carried at least to midthigh, no matter how low the fracture is in the shaft. Occasion-

ally a long external splint from axilla to foot is employed, as well as the extension and coaptation splints, to overcome a tendency to outward angulation. Sometimes this angulation can be more efficiently controlled by lateral traction, according to Bardenheuer's plan (Fig. 10). Posterior sagging of the fragments must be prevented to maintain the normal anterior convexity of the femur. A small pillow beneath the thigh usually overcomes this. Frequently for the first week or ten days of treatment, a rolled sheet has been used as countertraction from the perineum, its ends being fastened to the head of the bed on the same side as the fracture: unless this is used, it may be difficult to prevent

Fig. 10.—Fracture of shaft of femur (compound) in man, aged 23, treated by Buck's extension apparatus: *A*, before lateral traction, medial bowing of fragments, Aug. 23, 1919; *B*, during lateral traction, showing overcorrection, Sept. 2, 1919, and *C*, after removal of lateral traction, Sept. 15, 1919, showing good alinement.

the patient from being pulled down to the foot of the bed in spite of considerable elevation of the latter. After a week or ten days, when the shortening usually is overcome, the weight used for traction may be slightly diminished. But daily measurements should be taken to make sure that proper length is being maintained. We have used as much as 38 pounds (from 17 to 18 kg.) in this way in a case of comminuted fracture of the shaft, securing a perfect anatomic and functional result, the patient (a man, aged 40) being out of work only twenty weeks, and retaining his former job and wages.

In another man, aged 36, with an oblique fracture of the shaft, 34 pounds (15.5 kg.) of traction was used, but satisfactory reduction could not be secured, so the femur was plated. This patient also recovered perfect anatomic and functional results, was out of work only eighteen weeks, and resumed his former job and pay. In most patients, however, traction of from 15 to 20 pounds (7 to 10 kg.)

Fig. 11.—Fracture of shaft of femur in man, aged 35, Aug. 13, 1921; 4 cm. shortening; treated by Buck's extension, with enough weight to reduce shortening to 1 cm. after five days.

is sufficient to overcome shortening; and if reasonably good alinement is then secured we are satisfied to let the fracture unite in this position, even if perfect apposition of the bone ends has not been secured. We have learned that in most such cases, even in adults, good function is secured as early as if operation had been employed (Figs. 11 and 12). In the present series, operation was adopted in five cases among the fifteen adult patients, but in no case in children.

In children (under 15 years) we habitually employ a splint modeled on Hamilton's (1860). This consists of two long external splints

extending from the axillae to well below the feet, the lower ends of both splints being fixed in moderate abduction by a cross-bar (Fig. 13). Traction (by Buck's extension) is applied only to the fractured limb, but each lower limb is bandaged snugly to its corresponding splint. The splints (suitably padded) are fastened to the chest by means of a wide binder. This apparatus has the advantages of simplicity, and renders it easy to nurse the patients. Ten years ago or longer, we abandoned the use of circular plaster-of-Paris casts in the treatment of

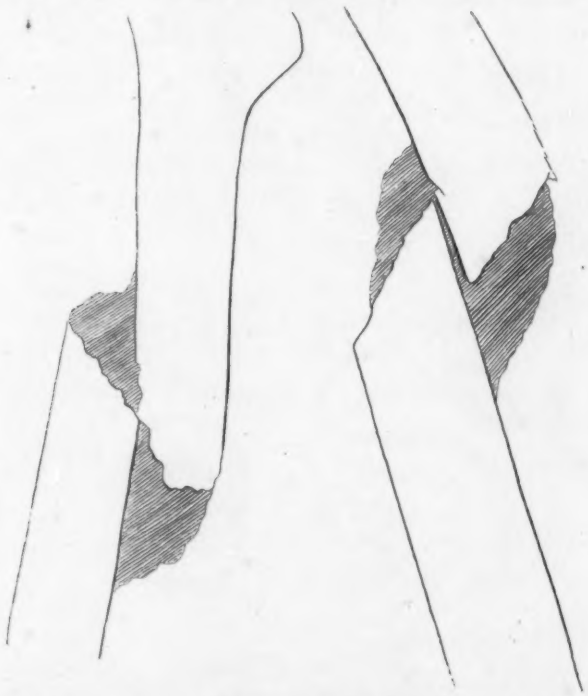

Fig. 12.—Fracture shown in Figure 11 after union: patient was in hospital ten weeks, out of work nine months (because he was receiving compensation, not for any apparent disability); resumed former job at same wages; moderate anatomic but good functional result. This case is on the borderline of those in which we believe operation (plating) indicated. In an older patient, but one not yet senile, or in a case in which there is more separation of the fragments, or with a more nearly transverse fracture (exposing less raw bony surface for repair), operation would be indicated to insure bony union. Comparison should be made with Figures 19 and 20.

fractures of the femur in children. We saw no advantages in their use, and observed that it was sometimes difficult to prevent and to detect slipping of the fragments and consequent shortening of the limb; moreover, the return of normal function seemed longer than in patients treated with less complete immobilization. However, our

patients who were treated in circular gypsum cases secured, eventually, as good function as the others. In fact, in none of the children under our care has the end-results shown any disability whatever (Figs. 14, 15 and 16); so it must be concluded that almost any form of treatment will secure a good result in the case of fractures of the femur in children.

Only in children under 2 years of age have we employed the vertical suspension plan of Bryant (1872). This is objectionable, theoretically, because combined flexion of the hip and extension of the knee makes the hamstrings relatively very short, tending to prevent correction of deformity at the site of fracture. Practically, however, this is immaterial, since all fractures of the femoral shafts in very young children tend to unite readily, and any deformity (however gross it may be when consolidation occurs) very soon is remedied by the growth of the child. In a few cases in babies, fractures of the femoral shaft have been treated in the fully flexed position with the thigh held against the side of the body by a triangular splint and the knee flexed.

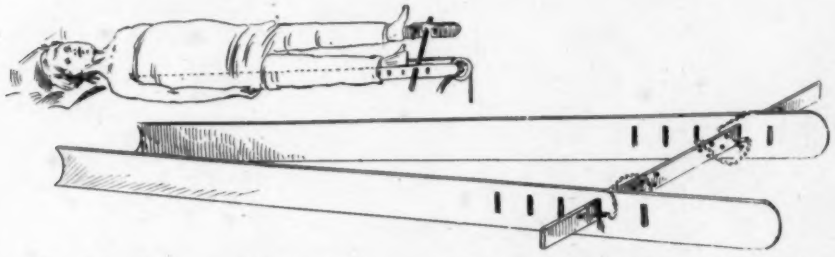

Fig. 13.—Splint useful in children modeled on that introduced by the late Dr. Frank Hastings Hamilton (1860).

We have seen two cases in infants of right angle deformity in the middle of the shaft spontaneously reduced by growth of the baby so that before the age for walking was reached no gross deformity remained, and even roentgen-ray examination showed very little.

It has been the custom of late years to decry the value of Buck's extension apparatus in the treatment of fractures of the femur, and to over-emphasize certain advantages claimed for traction in suspension, and for skeletal traction by means of the ice-tongs or some similar contrivance applied to the condyles. While we had sufficient experience during the Great War to appreciate the value of suspension treatment in cases of gunshot fractures, mostly infected, we have been unable to convince ourselves of its advantages in civil practice. We have not found that the patients under our care are any less comfortable and contented than those we have seen treated in other hospitals by traction in suspension; nor that their fractures are slower or less certain in

uniting; nor that their deformity is any greater; nor yet their average period of disability any longer. We are, moreover, firmly convinced that Buck's extension apparatus with a sliding foot splint is much simpler and easier to care for, and therefore much more likely to be efficient than any complicated method with overhead frames and numerous axes of traction and countertraction with balanced (or unhappily sometimes unbalanced) weights.

The Thomas knee splint, though very efficient for transport, is not suited for permanent use if extension is to be secured by traction against

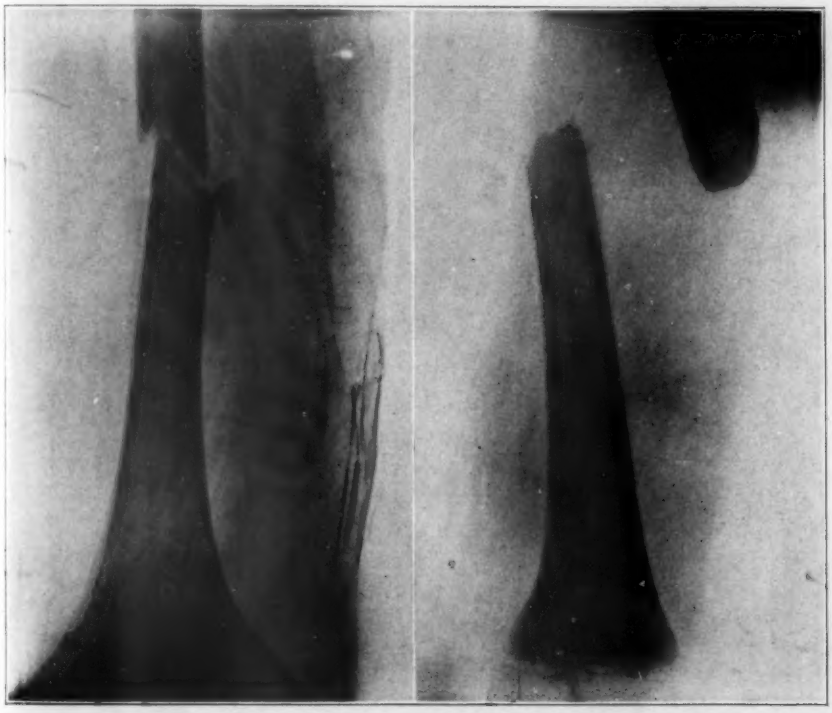

Fig. 14.—Fracture of shaft of femur in boy, aged 7 years, Nov. 16, 1914: marked displacement, irreducible under anesthesia; because ward had been put in quarantine for scarlatina this patient was not operated on but was treated in Hamilton splint, with Buck's extension.

the end of the splint itself with counterpressure against the tuberosity of the ischium: pressure sores are sure to develop. And if this method of employing the Thomas splint is abandoned, and traction is secured merely by fastening the patient's leg to the lower end of the splint, and attaching this in turn to the foot of the bed, and then securing countertraction by raising the foot of the bed from the floor and letting the patient's body slide up toward the head of the bed—if such a plan

is employed, we repeat, it presents no obvious advantages over the simpler method we have described of employing Buck's extension apparatus.

In this connection, it is interesting to call attention to a patient seen recently in consultation with Dr. John A. Boger of Philadelphia, under

Fig. 15.—Fracture shown in Figure 14, Jan. 14, 1915: good union by bridge of callus; bad anatomic result.

whose care the man came about a year after his injury. The patient, a negro janitor, aged 50, was injured, Jan. 22, 1924, sustaining a simple fracture of the lower third of the shaft of the left femur. He was taken at once to a well equipped hospital, where ice-tong traction was applied immediately to the condyles of the femur and the limb treated

according to the "modern" method by suspension from an overhead frame. He remained in this hospital three months. For six months longer he was treated by massage, etc.

In January, 1925, when examined by us he walked with a marked limp, his heel not touching the floor. He wore an extension shoe 3½ inches (9 cm.) higher than that on the normal foot. He had a range of motion in the knee joint of 50 degrees (from 110 to 160 degrees, counting 180 degrees as full extension of the knee joint). But as the lower fragment of the femur (which was about 15 cm. long) was displaced anteriorly on the upper fragment, and

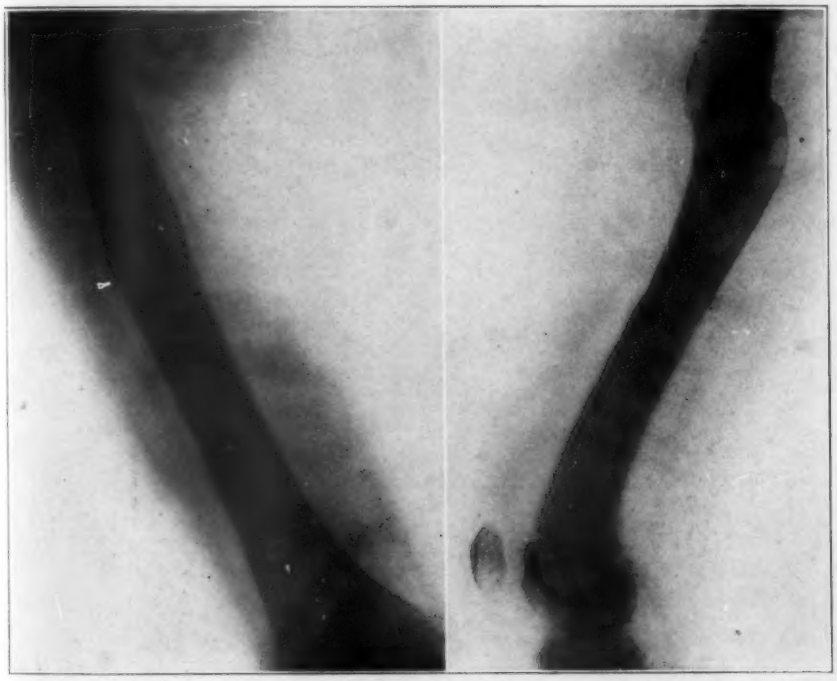

Fig. 16.—Fracture shown in Figures 14 and 15 eighteen months after injury, showing as good final anatomic result as could have been secured by operation; perfect function; period of disability three months.

made an angle with it of 135 degrees convex toward the extensor surface, this deformity resulted in making the apparent extension of the knee stop at 115 degrees with the long axis of the proximal fragment, while its apparent limit of flexion was about 65 degrees. In addition to this marked anteroposterior displacement, there also was lateral displacement of the fragments, at an angle of 150 degrees, convex laterally, giving the patient a marked bow-leg deformity. Bony union was present. The actual shortening was about 1 cm., while the apparent

shortening was about 5 cm., due almost entirely to the angulation of the fragments (Fig. 17). The patient had not yet been able to resume his usual work.

The patient whose history has just been cited has an extremely bad result; this no one can deny. And if his case was altogether exceptional it would be unjust to use it as an example. But quite a number of similar if less disabling results of the treatment by ice-tongs traction have come to our notice, showing that it is a method that requires more skill and experience in fracture work than is possessed by most surgeons, even by those who pass for good surgeons. The result just

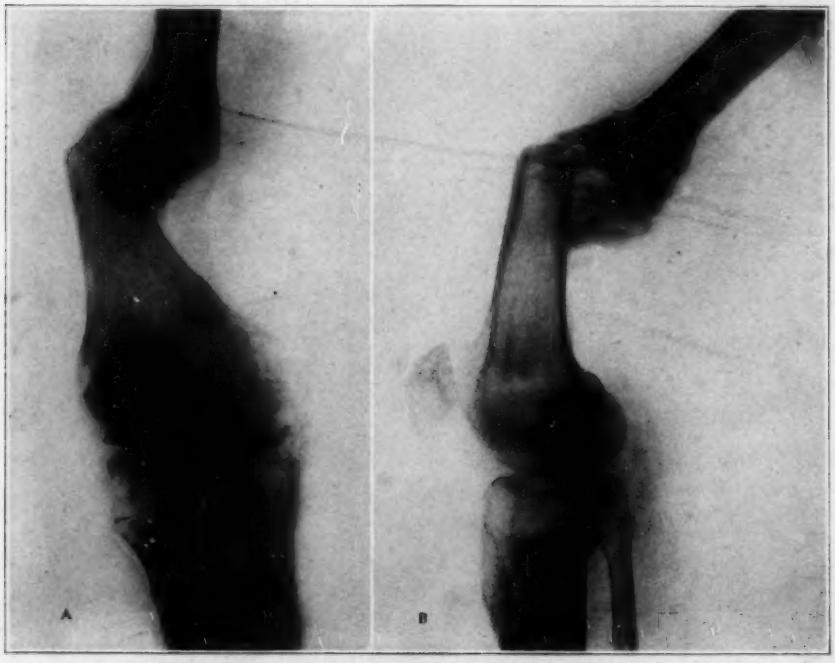

Fig. 17.—Fracture of shaft of femur (simple) in man, aged 50, treated elsewhere by a supposedly competent surgeon in a well equipped hospital specializing in traumatic surgery; ice-tongs were immediately applied to condyles; patient was in hospital three months; bad anatomic and bad functional result; period of disability about one year (text): *A*, anteroposterior view; *B*, lateral view one year after injury.

cited is certainly a far worse result than any we have secured in our own cases, or, we may add, in any patient we have ever seen treated by means of Buck's extension in the extended position without suspension. We do not for a moment wish to deny that skeletal traction from the femoral condyles has secured in many cases most excellent results. We merely wish to record our experience that, up to the present at

least, we have ourselves encountered very few cases in civil surgery in which its use seemed desirable. We believe that it is most indicated in some of the cases among the class about to be discussed.

FRACTURES INVOLVING THE KNEE JOINT

There were eleven cases of fractures involving the knee joint in our series, with two deaths, and two patients who recovered only after amputation of the thigh. We have subdivided the cases into two classes:

(*a*) *Supracondylar Fractures.*—In these the line of fracture involves the shaft not more than 10 cm. (in adults) above the joint surfaces, thus involving the joint indirectly, just as a supracondylar fracture of the humerus involves the function of the elbow joint. There were six patients in this class, with one death from "senility" two months after the injury in a woman, aged 73, already an inmate of a ward for incur-

TABLE 13.—*End-Results of Seven Cases of Fracture Involving the Knee Joint (Including Two Amputations*)*

Anatomy		Function		
		Good	Moderate	Bad
Good	1	0	1	0
Moderate	4	1	3	0
Bad	2	0	2	0
Total	7	1	6	0

* Bad anatomic, moderate functional results.

ables. Two of the six patients had compound supracondylar fractures; in one of these primary amputation was refused, and the patient was treated by suspension and traction by a Steinmann pin through the condyles, but on the fourth day developed gangrene of the leg from thrombosis of the popliteal vessels: amputation then was permitted, and recovery followed. Recovery in the other compound supracondylar fracture also occurred, but this patient has not been traced. Omitting these two patients and one death, we have left only three patients in whom the end-results are known: one child recovered after operative reduction with only a moderately good anatomic result but perfect function; while two adults secured only moderate functional as well as moderately good anatomic results. One, a woman, aged 48, with preexisting bilateral arthritis of the knees, finds her broken thigh less painful than the uninjured one; she has 2 cm. of shortening and flexion of the knee only to a right angle, but is able to do all her own housework. The other, a man, aged 63, has flexion of the knee only to 150

degrees, slight genu valgum and 1 cm. of shortening; he was out of work for twenty-two months, cannot resume his former job, and makes less wages than before his accident.

(*b*) *Fractures into the Knee Joint Through One or Both Condyles.*—There were five such cases in our list, with one death after three days from shock in a man, aged 50, who sustained a compound comminuted fracture with dislocation of the knee, double fracture of the pelvis, etc. Another patient with a crush of the knee joint (compound) refused primary amputation; so a primary excision of the joint was done; the patient developed gas gangrene but recovered after amputation of the thigh on the sixteenth day. Of the three remaining patients, one has not been traced; one, who also had a compound fracture of the shaft of the other femur, recovered after an open reduction of the simple fracture involving the right knee joint. The fifth patient, with a simple fracture into the knee joint, recovered with a nearly stiff but painless knee; he was out of work only five months and retained his former job and wages.

PERIOD OF DISABILITY

The period of disability is shown for all types of fractures of the femur in Table 14.

The American Surgical Association's figures showed that only 58 per cent. of the patients had a period of disability of less than six months; and only 64 per cent. returned to work in less than nine months. In the present series, nearly 84 per cent. returned to work in less than nine months. In the tables of the American Surgical Association, 36 per cent. of the patients with fracture of the femur were disabled for more than nine months; in the present series, less than 17 per cent. were disabled for so long. Among the former cases, 19 per cent. of the patients were disabled for more than twelve months; in the present series, less than 10 per cent. were disabled for so long.

COMPOUND FRACTURES

There were only nine compound fractures among the 111 cases of fracture of the femur in this series: five of these involved the shaft, with one death, and four involved the knee joint, also with one death.

The compound fractures of the shaft of the femur were in the following cases:

1. A girl, aged 6 years, Aug. 20, 1913, fell from a second story window; a small wound was made by protusion of the bone. This was treated as a simple fracture; no operation was performed. The patient was in the hospital for seven weeks and disabled for three months. Recovery was made with bad anatomic result (forward angulation which gradually straightened spontaneously after union) but perfect function.

TABLE 14.—*Effect of Good Anatomic Result in Lessening Period of Disability*

Site	Anatomic Result	Total	Period of Disability: Under 3 months	Under 6 months	Under 9 months	Under 12 months	Over 12 months
Intracapsular	Good	6	2	0	1	3	0
	Moderate	4	0	1	0	1	2
	Bad	1	0	0	1	0	0
Trochanteric	Good	11	1	5	4	0	1 *
	Moderate	5	0	0	1	1	3
	Bad	0	0	0	0	0	0
Below trochanters	Good	4	1	2	1	0	0
	Moderate	3	1	1	1	0	0
	Bad	1	0	0	1	0	0
Shaft (children)	Good	11	9	2	0	0	0
	Moderate	9	9	0	0	0	0
	Bad	4	4	0	0	0	0
Shaft (adults)	Good	8	2	3	3	0	0
	Moderate	4	0	2	1	1	0
	Bad	1	0	1	0	0	0
Condyles	Good	1	0	0	1	0	0
	Moderate	4	0	3	0	0	1
	Bad	0	0	0	0	0	0
All sites	Good	41	15	12	10	3	1
	Moderate	29	10	7	3	3	6
	Bad	7	4	1	2	0	0
Period of disability known in		77	29	20	15	6	7
			49 (63.6%)		20%	13 (16.8%)	

* Disabled from arthritis of both knees present before patient fractured femur.

TABLE 15.—*Average Period of Disability in Cases Terminated Under Twelve Months*

Cases in Present Series: Site of Fracture	Cases	Average Period of Disability	Figures of American Surgical Association (1915): Site of Fracture	Cases	Average Period of Disability
Neck	8	7 months	Neck	32 *	6.5 months
Trochanters	13	7 months			
Below trochanters	8	4.6 months			
Shaft	36 †	3.87 months	Shaft	168 ‡	6.3 months
Condyles	3	5 months			
Total	68	5.3 months	Total	200	6.3 months

† This includes twenty-four cases in children, with an average period of disability of 2.89 months; and twelve cases in adults, with period of disability of 5.83 months.

* This includes fractures at base of neck as well as intracapsular fractures.

‡ This includes about 40 per cent. children, 60 per cent. adults.

2. A man, aged 25, Oct. 24, 1914, was wounded while hunting by the discharge of a gun at close range; the upper thigh was filled with bird shot. Death followed in a few hours from shock.

3. A man, aged 59, Oct. 31, 1914, while intoxicated fell from and was run over by his own wagon. He suffered from marked shock and free bleeding, which was checked by packing a large deep wound of the soft parts. He also had a simple fracture of the other femur. He was gravely ill from shock and hemorrhage for many days. The other femur (because of worse displacement) was plated after nineteen days. He refused operation on the side of the compound fracture. He was in the hospital for three and one-half months, out of work for six months in all; he resumed his former job at the same wages. He had a moderate anatomic result but good function in the thigh that was the seat of the compound fracture.

4. A man, aged 26 years, Dec. 4, 1908, fell from a height, suffering a compound comminuted fracture of the shaft of the left femur, with serious injury of the skin and muscles, great shock (temperature 95.4 F.) but not much bleeding. He also had a simple fracture of the other femur into the knee joint, with a deformity requiring operative reduction; also fracture of the left elbow and of the upper and lower jaws. This patient was treated by early operation (eight days) on the other femur, the fragments of which were irreducible and threatened to perforate the skin, and by delayed operation (one month) on the compound fracture. The anatomic result in the latter was good, but some limitation of flexion of the knee remained when the patient was last seen some six months after the accident.

5. A man, aged 23, Aug. 19, 1919, was hurt in a motorcycle accident, receiving a small deep wound of the soft parts, which was packed on account of bleeding. The case was treated as simple fracture. The patient was in bed for fifty-two days; then was walking in the ward for eight days, when he stumbled against a bedstead and refractured the femur at the same site. He was in bed for a second period of eighty-one days. The total stay in the hospital was five months; he wore a supporting brace for several months, and was out of work for ten months. He recovered with 3 cm. shortening and flexion of the knee limited to a right angle. He resumed his regular job at the same wages.

The compound fractures of the femur involving the knee joint directly or indirectly were in these cases:

1. A man, aged 40, Oct. 17, 1922, was crushed above the condyles of the femur. He refused amputation on admission, and was treated by débridement and excision of the wound, as well as by overhead traction from a steel pin through the condyles. He developed gangrene from thrombosis of the popliteal artery. Amputation at midthigh was done four days after the injury. He had an uneventful recovery.

2. A man, aged 25, Dec. 3, 1911, suffered crush of the knee joint (femur and tibia). He refused amputation on admission. Primary excision of the knee joint was done on the day of injury. He developed gas gangrene. Amputation was performed through the thigh sixteen days after the injury. An uneventful recovery followed.

3. A man, aged 50, Dec. 2, 1920, suffered crush of the lower end of the femur with a widely opened knee joint, simple dislocation of the other knee joint, and double fracture of the pelvis. Death followed three days after the injury.

4. A man, aged 48, Nov. 28, 1916, received a comminuted, compound supracondylar fracture from a crush in machinery. There was serious injury of the skin, but not serious injury of the muscles; the circulation was good. This was treated as simple fracture. The patient was in the hospital for eight weeks. He recovered with 1.5 cm. of shortening, and with slight motion in the knee joint on discharge. He was not traced.

Among the seven surviving patients with compound fracture of the femur, in two cases the wounds became infected. In both of these the lesions were so serious that primary amputation had been advised but was refused. Both patients had to have their thighs amputated within a few days—one for gangrene from arterial thrombosis, the other for gas gangrene. Four of the other five patients were treated as if they had sustained simple fractures, the wounds being allowed to heal under sterile dressings, after primary surgical cleansing but without any formal operation such as débridement or excision. Only one patient of the five required operative treatment, and this had to be delayed for a month, owing to multiple injuries; by this time the wound of the compound fracture had entirely healed.

The results in these cases of compound fracture are summarized in Table 16.

OPERATIVE TREATMENT

In this series of 111 cases of fracture of the femur, operative treatment was adopted ten times, or in 9 per cent. of cases. This does not include two cases of amputation of the thigh for compound crushes of the knee joint, nor one case of aspiration of bloody effusion from the knee joint and injection of 2 per cent. formaldehyd-glycerin solution. The operations employed are given in Table 17.

The indications for operation in our estimation are inability to secure or to maintain sufficiently accurate reduction to ensure (1) bony union and (2) absence of disabling deformity. In children such conditions scarcely ever arise; almost without exception deformity in children will be spontaneously corrected. In a fracture of the shaft of the femur occurring during birth, first seen by us at the age of 13 days, firm union had already occurred with the fragments at a right angle with each other; we were able to assure the anxious parents and family physician that the deformity would be spontaneously corrected. At the age of 3 months, scarcely any trace of deformity could be seen in skiagraphs, and none at all could be found clinically. In another baby, aged 3 months, treated by flexion of the thigh against a triangular splint one side of which was bandaged to the abdomen, the fragments at the time of consolidation formed an angle of 100 degrees; but before the child was old enough to walk this deformity had been spontaneously corrected. When seen last, at the age of 7 years, no clinical deformity

remained, and only a very little bend could be seen in the skiagraph. It was observation of the following case which impressed on our minds the ability of Nature to remodel the bones in childhood:

M. G., a boy, aged 7 years, Oct. 31, 1914, was run over by an automobile, suffering a nearly transverse fracture about the middle of the femur, with very wide separation of the fragments, irreducible by ordinary means (Fig. 14). Operation was advised and accepted by the parents. On the morning set for operation,

TABLE 16.—*End-Results in Six Cases of Compound Fracture of Femur*

		Function		
Anatomic Result				
Good	1	0	1	0
Moderate	2	1	1	0
Bad	3*	1	2*	0
Total	6	2	4	0

* Two patients recovered only after amputation.

TABLE 17.—*Operations in a Series of One Hundred and Eleven Cases of Fracture of the Femur*

						Result	
Age	Date	Site	Interval from Injury to Operation	Operation	Period of Disability	Anatomic	Functional
20	6/17/22	Neck	20 days*	Screw	7 months	Good	Moderate
52	1/ 2/24	Below trochanters	13 days†	Plate	Retired	Shortening; 3 cm. outward angulation	Moderate
34	8/26/12	Below trochanters	13 days‡	Plate	9 months	Good	Good
23	8/ 7/11	Shaft	21 days*	Plate	7 months	Good	Good
36	8/ 4/16	Shaft	17 days§	Plate	4 months	Good	Good
59	11/18/14	Shaft	19 days†	Plate	6 months	Moderate	Moderate
20	10/21/14	Shaft	12 days	Plate	5 months	Good	Good
26	1/ 2/09	Left shaft	20 days†	Plate	? months	Good	Moderate
26	12/12/08	Right condyles	8 days	Open Reduction	? months	Good	Moderate
9	9/27/24	Supracondylar	9 days	Open Reduction	5 months	Moderate	Good

* Patient did not come under our care until more than two weeks after injury.
† Operation delayed because of patient's general condition.
‡ Operation delayed because of condition of soft parts.
§ Operation delayed for purpose of first trying nonoperative means.

a quarantine was established against the children's ward on account of scarlatina. Accordingly, the child was again dressed on a Hamilton splint and nonoperative treatment was continued. In spite of the very wide separation of the fragments, firm union occurred within four weeks (Fig. 15); the total period of disability was three months, and eighteen months after injury there was no disability, no shortening, no palpable deformity, and even the roentgen-ray examination showed very slight distortion (Fig. 16).

But in adults this adaptive power exists to a very much less degree, and in most cases it is imperative to correct any gross displacement. Usually this may be done gradually (in the course of a few days) by weight extension (Figs. 5 and 18). This is more easily done in the case of shaft fractures than in those near joints. But in the latter cases accurate reduction is especially important. Even in children a joint fracture requires good reduction to ensure good function. Accordingly, the only time operation was adopted in a child in the present series

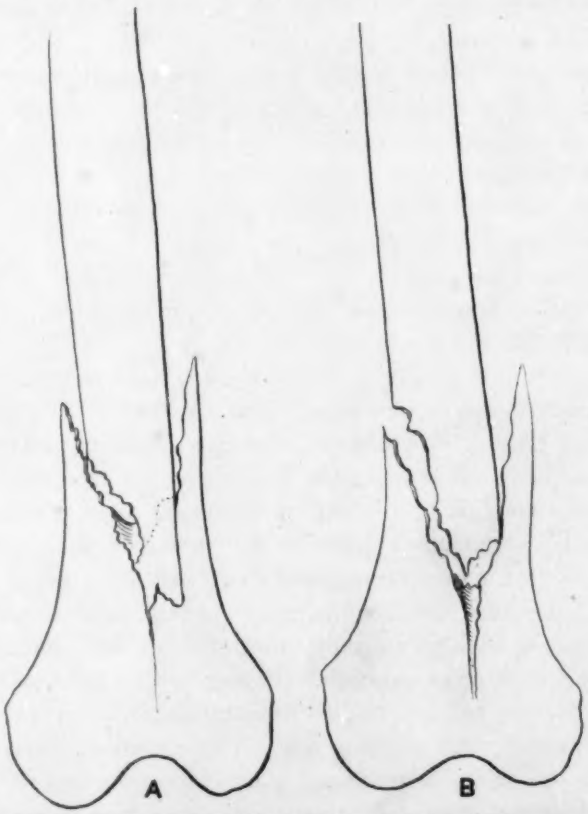

Fig. 18.—Comminuted supracondylar fracture of femur in man, aged 63: *A*, Sept. 5, 1919, before application of dressings, 3 cm. shortening; *B*, Sept. 6, 1919, after 28 pounds (13 kg.) traction for twenty-four hours by Buck's extension apparatus; no shortening; patient was in hospital eleven weeks; recovery with slight knock-knee deformity, limited flexion of knee and lessened earning power.

(among twenty-eight fractures occurring in those under 15 years of age) was in a case of supracondylar fracture in a boy, aged 9, with marked effusion into the knee joint; closed reduction under general anesthesia having failed on two attempts, the fragments were replaced by incision, the knee joint being evacuated at the same time, nine days after injury.

Though the fragments subsequently slipped, giving only a moderate anatomic result at the time of consolidation, all traces of deformity disappeared within five months, giving a perfect functional result. Every patient in this series less than 15 years of age recovered perfect function, whether or not the position of the fragments at the time of consolidation was good.

Joint fractures, however, and especially those near the hip, usually may be accurately reduced without incision, either by position alone (Fig. 4), or by traction (Fig. 5). Only in one case of fracture through the neck did operative reduction seem proper (Fig. 7), and it is possible that fixation in an abduction cast without open reduction and fixation of the fragments even in this patient might have secured as good a result as was obtained by operation. Owing to the flaillike condition of the lower extremity resulting from infantile paralysis, however, it was thought that open reduction and direct fixation afforded a greater certainty of securing good function. As a matter of fact, the result is all that could have been desired.

No operation was done in any of the thirty-three patients with fractures through the trochanters.

In ten cases with fractures below the trochanters, operation (plating) was undertaken in two patients, at an interval of twelve years; in both cases because of gross displacement that seemed to render the probability of bony union doubtful. In the first patient (1912) in whom the fragments were back-to-back, the anatomic and functional results were perfectly satisfactory; but in the second patient (1924) only moderate function was obtained, and there developed outward angulation of the fragments some months after apparent consolidation in good position, resulting in ultimate shortening of 3 cm. and slight limp, with complaints of pain after exertion. This patient, a man, aged 52, was injured by falling off a truck while intoxicated. On admission his fragments were in fair position and no operation was contemplated; but within a few days he developed mania a potu during the night and fell out of bed; subsequent roentgen-ray examination showed the fragments back-to-back as already described. Some weeks after the man's discharge from the hospital, walking with crutches and without deformity, he developed outward angulation at the site of fracture, with shortening of 3 cm. Roentgen-ray examination showed the plate had been pulled loose from the tronchanteric fragment, while holding fast to the shaft fragment. This was clearly due to an error on the operator's part, and not to any fault inherent in the method of treatment. The trochanteric fragment was composed of cancellous bone, and the screws used in it (at any rate some of them) should have been much longer

than the screws that were used; these held firmly in the shaft fragment composed of cortical bone, for which alone they were suited. Or the plate should have been bound to the upper fragment by an encircling band or wire.

In five of sixteen fractures of the shaft of the femur in adults operation was employed, but not once in twenty-four fractures of the shaft in children. In these cases also the indication for operation was such

Fig. 19.—Transverse fracture of shaft of femur in man, aged 20, Oct. 9, 1914; even if traction could have overcome shortening union without end-to-end apposition would have been unlikely because of the small cross-area of fractured surfaces; operation indicated. Comparison should be made with Figures 11 and 12.

displacement of nearly transverse fractures (Fig. 19) as to render union improbable even if shortening were overcome by weight extension. Three of these patients recovered with perfect anatomic and functional results, the average period of disability being a little over five months. In the two other patients, both of whom had fractures of both femurs, only moderate function was secured.

Among eleven fractures involving the knee joint directly or indirectly, operation was employed in two; in both patients open reduction without direct osteosynthesis proved sufficient (Table 17).

If operation is to be employed, this fact should be determined without unnecessary delay. In our own series, however, it had to be post-

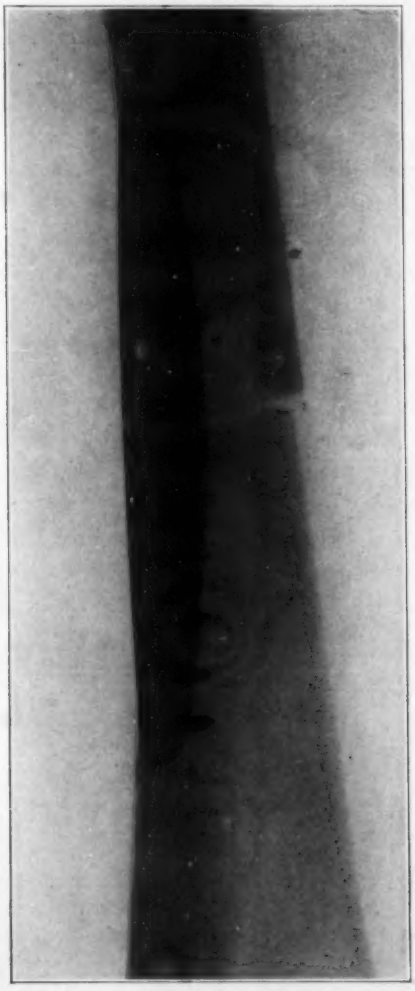

Fig. 20.—Fracture shown in Figure 19 with application of plate twelve days after injury; patient was in hospital forty-six days, out of work five months; he enlisted in army four months after leaving hospital and served throughout the Great War.

poned in several instances because of the precarious condition of the patients, who were suffering from multiple injuries.

Operation is not to be countenanced except when done by competent surgeons in hospitals well equipped for this kind of work, both as

regards personnel and instruments. Instrumental technic should be employed throughout, the hands of the surgeon, assistants and nurses never entering the wound nor touching any part of any instrument nor any sponge which is to be introduced into the wound. Only by adherence to the strictest asepsis can foreign bodies used for fixation be well tolerated indefinitely in the tissues.[10] Steel plates are, in our opinion, more satisfactory for fixation of recent fractures of the femur than autogenous bone transplants or artificial bone.

SUMMARY

This is a study of a consecutive series of 111 cases of fracture of the femur. Of the ninety-eight patients who survived their injuries, eighty-seven, or 89 per cent., were traced. The definitions of anatomic and functional results adopted by the Fracture Committee of the American Surgical Association have been adhered to.

Anatomic Results.—Among these eighty-seven patients, anatomic reposition of the fragments was secured in forty-four patients, about 50 per cent. Moderately accurate reduction was obtained in thirty-four patients, 40 per cent.; and in nine only was the position of the fragments bad at the time of consolidation.

Functional Results.—Fifty-five patients, 63 per cent., had no functional disability whatever; twenty-six, 30 per cent., had moderate functional results, and only six, 7 per cent., were incapacitated. Three patients in the latter group had had fractures through the neck of the femur, and three had had fractures through the trochanters. No patients with fractures below the trochanters, through the shaft, or with fractures involving the knee joint secured bad functional results. These functional results may be compared with figures published by the Fracture Committee of the American Surgical Association, showing the average results to be good function in 59 per cent. of cases, moderate function in 27 per cent., and bad function in 14 per cent. of cases.

Period of Disability.—Nearly 64 per cent. of the patients returned to work in less than six months; nearly 84 per cent. returned to work in less than nine months. The corresponding figures of the American Surgical Association showed that only 64 per cent. returned to work in less than nine months. The average period of disability in the present series was five and three-tenth months, or one month less than the average period of disability given by the American Surgical Association.

No comment is required on the patients who recovered with a good anatomic result (Table 18). Of the thirty-four patients who secured

10. Ashhurst, A. P. C.: Removal of Screws and Plates after Insertion in Bone, Ann. Surg. **81**:528 (Feb.) 1925.

only a moderate anatomic result, twelve had and twenty-two had not measurable shortening, but in no case was the shortening over 2 cm.; the only other reason for recording any of these thirty-four cases as other than good anatomic results is that at the time of consolidation the fragments were in a position of approximate reduction only, not of accurate anatomic reposition. Among the nine patients recorded with bad anatomic results, two had amputation of the thigh for gangrene, three had nonunion (fractures through the neck), two had notable

TABLE 18.—*Summary of End-Results in Eighty-Seven Cases of Fracture of the Femur*

Anatomic Result	Cases	Functional Result Good	Moderate	Bad
Good:				
Through neck	6	2	4	0
Trochanters	13	9	3	1
Below trochanters	4	4	0	0
Shaft	20	19	1	0
Condyles	1	0	1	0
Total	44 (50%)	34 (77%)	9 (21%)	1 (2%)
Moderate:				
Through neck	5	0	2	3
Trochanters	9	2	5	2
Below trochanters	2	1	1	0
Shaft	14	11	3	0
Condyles	4	1	3	0
Total	34 (40%)	15 (44%)	14 (42%)	5 (14%)
Bad:				
Through neck	1	0	1	0
Trochanters	0	0	0	0
Below trochanters	1	1	0	0
Shaft	5	5	0	0
Condyles	2	0	2	0
Total	9 (10%)	* 6 (66%)	3 (33%)	0
Grand Total	87 (100%)	55 (63%)	26 (30%)	6 (7%)

* This apparently large number of bad anatomic results is composed largely of fractures of the shaft of the femur in children, all of whom recovered perfect function.

angulation of the fragments, and three only had shortening of more than 2 cm. (one had 4 cm., two had 3 cm. of shortening).

As regards the functional results, fifty-five patients had no disability whatever. Among the twenty-six who are recorded as having moderate function, one had, and twenty-five had not, any swelling of the soft parts; nine had, and 17 had not, a limp (eight fractures of the neck or trochanters, one of the shaft); ten had, and sixteen had not, pain in damp weather or after much exertion (seven of the neck or trochanters, two of the shaft, one of the knee); twelve had, and 14 had not, lessened endurance (ten of the neck or trochanters, one of the shaft, one of the knee); seventeen had, and nine had not, interference with joint func-

tion (seven fractures in region of the hip, six of the shaft, four of the knee; causing disability in the hip joint in seven cases, and in the knee joint in ten cases).

Of the six patients who recovered with bad function, three were aged respectively 81, 86 and 87 years; of the remaining three, one complained of swelling, and all three had limp, pain, lessened endurance, and interference with joint function.

Methods of Treatment.—(*a*) For fractures through the neck (intracapsular) the abduction cast introduced by Whitman is preferred; nine out of twelve traced patients so treated secured bony union.

(*b*) For fractures at the base of the neck and for comminuted fractures through the trochanters, either the abduction cast is used or the patient is treated as for fracture of the shaft of the femur; the choice depends on the level of the fracture and the best method of overcoming deformity. In all fractures near joints, it is very important to secure accurate reduction.

(*c*) For fractures below the trochanters, fractures of the shaft and most supracondylar and intercondylar fractures, Buck's extension apparatus is employed, with the patient's leg resting on a sliding splint, to overcome friction. Enough weight is employed to overcome shortening. Coaptation splints are used when needed. In fractures not involving the functions of the hip or knee joints, it is considered sufficient, particularly in children, to secure such degree of reduction only as will ensure the occurrence of union, without shortening, and without disabling deformity. Only when these desiderata seem unattainable without it is operative reduction employed.

(*d*) Operation was employed in 9 per cent. of the cases, and less often in recent years than formerly—only three times in the last eight years.

UMBILICAL HERNIA

A METHOD OF OPERATIVE TREATMENT *

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BALTIMORE

The Mayo operation for umbilical hernia was a great advance over the previous unsatisfactory methods of treatment. Ample evidence of this is found in the acclaim with which the operation is hailed in textbooks and other publications appearing during the years following its introduction. It became the standard surgical procedure and is so regarded today. Various minor modifications in the arrangement of flaps and sutures have been published, without material change in the principles of operation. Perhaps the present suggestion may seem merely another such modification, but it is believed that it differs in its basic mechanics and is presented for what it is worth. I have done only the Mayo operation until recently. One patient operated on by this method some six years ago returned after about three years with a slight but definite recurrence consisting of a bulge at the extreme lateral margin of the repair. The trouble was so slight that reoperation was not advised and to this day he has needed nothing other than an elastic supporter. On consideration, however, the case seemed to demonstrate an inherent weakness in the operation, although this particular recurrence may possibly have resulted from some defect of performance. Even so, it remains true that the lateral angles of the transverse repair as performed in the Mayo operation are points of potential weakness, and personal reports of recurrences from other surgeons confirm this fact. No matter how wide the overlap of the flaps in the median line, or how strongly they are sutured, it is apparent that this overlap progressively diminishes as the lateral angles are approached, and at and near the angles there is no overlap. This remains true even when the original hernial opening is extended well to the sides to increase the depth of the overlap in the midline. An illustration is reproduced here from "Keen's System of Surgery" of the Mayo operation, with the weak area pointed out (Fig. 1).

The method herewith presented is designed to avoid this weakness. To date it has been done in only five cases, and sufficient time has not elapsed to test even these five, the oldest being of eleven months' standing. The purpose in publishing the method so early is to obtain additional experience from any who may desire to give it a trial.

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* From the surgical department of Johns Hopkins University Medical Department.

Little description is necessary to add to the illustrations of Mr. Didusch. The usual transverse eliptical incision is made, surrounding the umbilicus and carried down to the anterior sheath of the recti muscles all around. The neck of the sac is isolated, the sac opened, and its contents dealt with as conditions may require to secure reduction. Then the sac and skin immediately about the umbilicus are excised leaving only a narrow margin of peritoneum about the hernial orifice. This orifice is not enlarged, but is closed by mattress sutures of strong silk or catgut so as to convert the oval or round orifice into a straight transverse line of closure (Fig. 2). It should be noted that the extreme

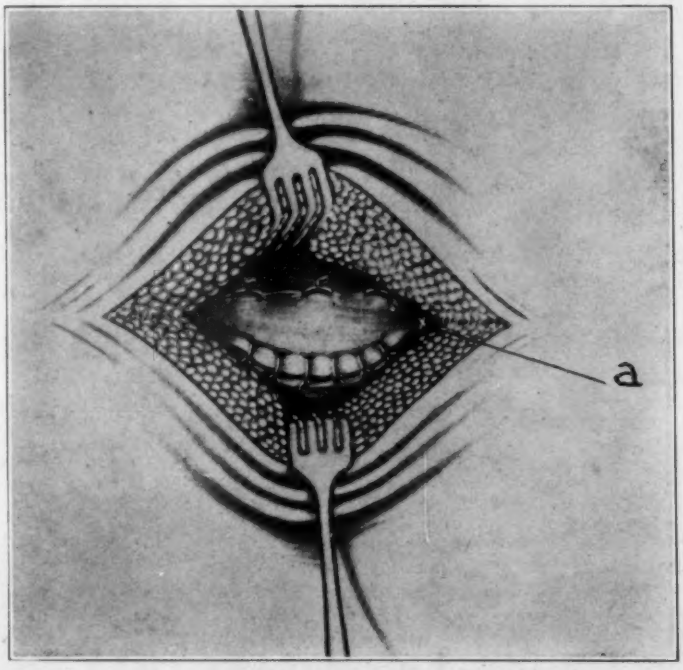

Fig. 1.—Mayo operation, from Keen's "System of Surgery:" *a* points to *x* at weak angle of repair.

sutures on either end are so placed that they straddle the actual margin of the defect; that is, one arm of the mattress crosses just within the lumen of the opening and the other arm of the same suture takes its two bites of anterior sheath entirely lateral to the opening, thus puckering the anterior sheath into a fold to either side of the neck of the sac (Fig. 3).

The second row of sutures is also a series of interrupted mattress stitches, overlapping the first row, which they bury, and forming another transverse line of closure over the first (Fig. 4). The span

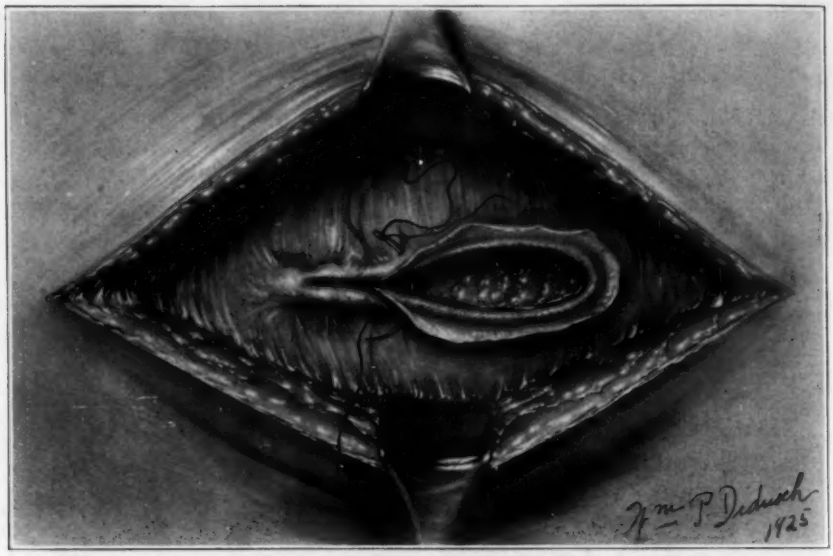

Fig. 2.—First row of mattress sutures closing hernial orifice in transverse direction being placed.

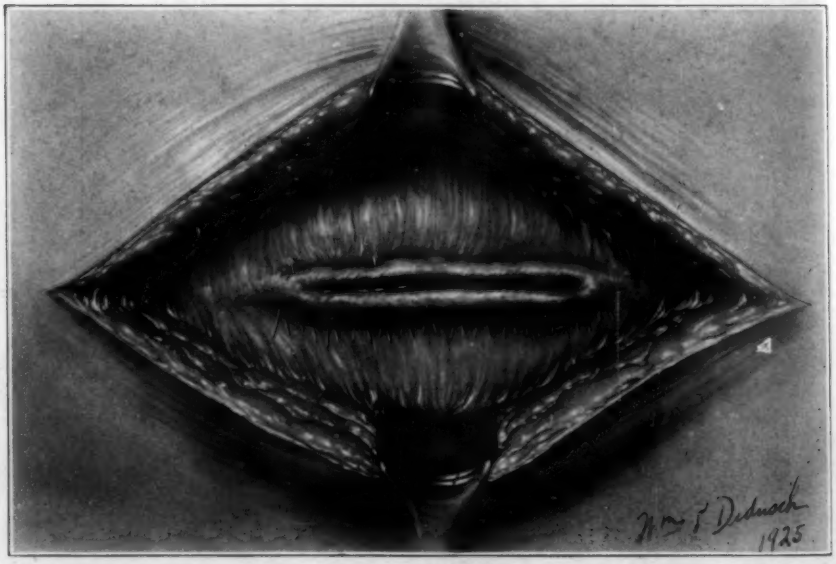

Fig. 3.—First row of sutures completed; hernial orifice closed.

of each of these stitches is about 1 cm. wider than the first row of stitches, so that when they are tied an inverted buttress of anterior sheath about 1 cm. in depth is turned inward over the first layer of closure. The point of especial emphasis is that this second row of sutures begins well lateral to each end of the first row, which simply closed the hernial orifice. They may well be carried 3 or 4 cm. to either side beyond the ends of the first row, and thus effectually do away with the weak angle pointed out at the beginning of this paper. This angle is buried under a firm double buttress of anterior sheath

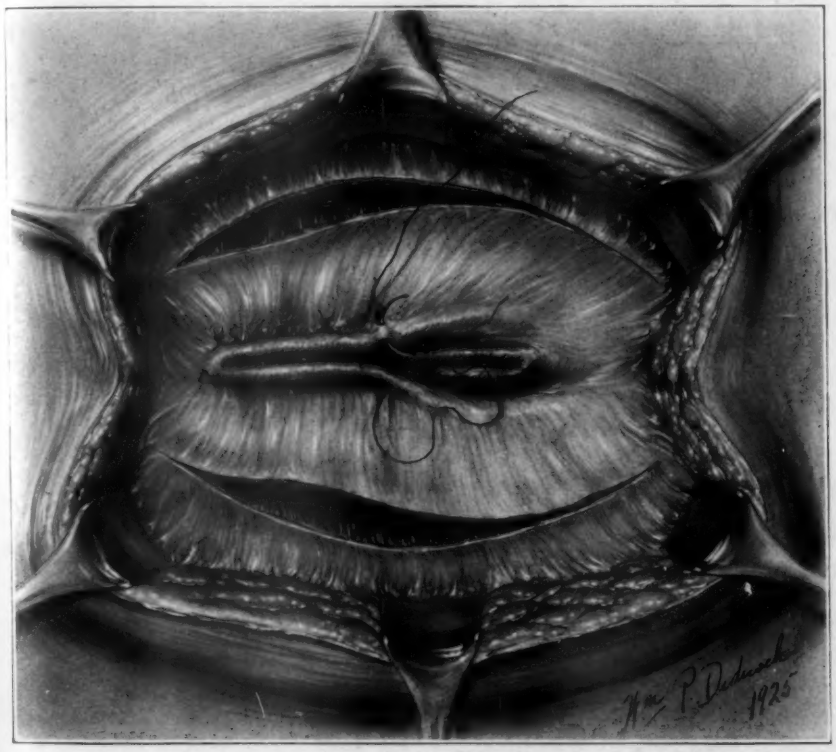

Fig. 4.—Placing of second row of sutures, which bury the completed first row by folds of anterior sheath.

(Fig. 3). In three of the patients operated on, all stout multipara, the hernia neck was large but there was a general slackness of the abdominal structures, so that no difficulty whatever was experienced in placing and tying the second row of sutures without undue tension. The repair, when finished, seemed very solid and strong, and the second suture line took up much of the slack of the abdominal wall. In the other two patients, both men with firm muscular abdominal walls, the orifice of the hernia was much smaller, but the whole abdomen was

more taut with little slack. In these cases two wide curved incisions were made through the anterior sheath, like parenthesis marks running transversely. They were about 6 cm. above and below the level of the umbilicus, respectively, and divided only the sheath, leaving the rectus muscles intact (Fig. 5). When the second row of sutures was placed and tied, these acted as relaxation incisions, permitting the sheath to be slid toward the umbilicus from above and from below. The sheath, however, was not dissected up from the muscle as a flap, but simply slid over it. The relaxation incisions naturally were widened

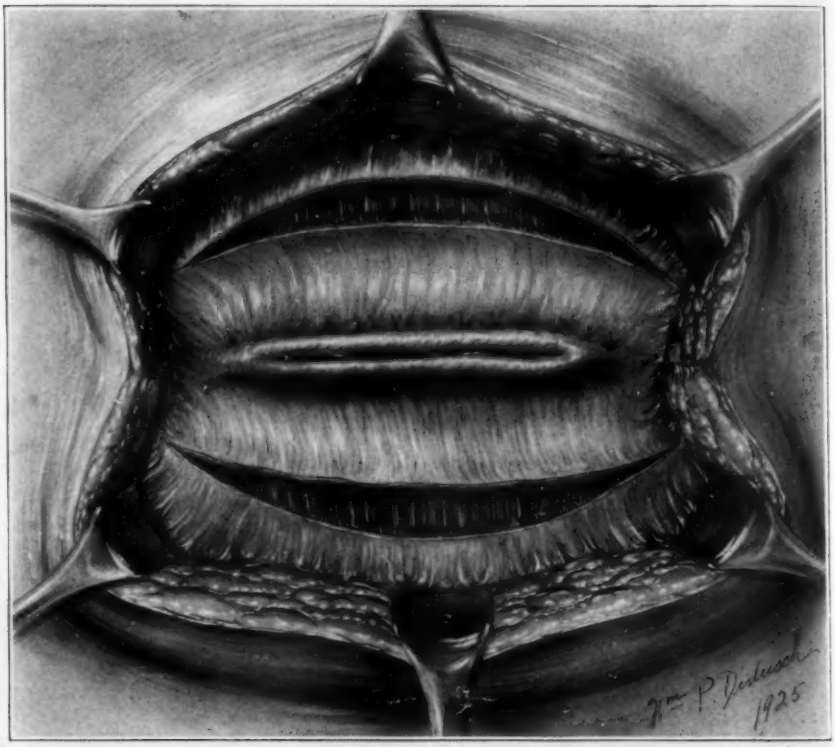

Fig. 5.—Second row of mattress sutures finished, completely burying first row and extending well beyond first row on either end; relaxation incision in anterior sheath above and below line of suture shown, although not always used.

somewhat, but as the muscles were strong and intact this was not felt to impair the integrity of the abdominal wall to any material degree. That this impression is well founded is borne out by the work of Dr. Amos Koontz, in the surgical Hunterian Laboratory of the Johns Hopkins University Medical Department. In the course of extended experimental studies of fascia and muscle sheath reactions, Dr. Koontz made numerous extensive removals of the anterior sheath of the rectus

abdominis muscles. He found that the denuded muscle quickly became invested in a new sheath of strong fibrous tissue, and showed no tendency to weakness or bulging at any time.[1] This additional step of providing relaxation incisions may often not be needed. At the end of these two operations also the repair gave the impression of great strength and solidity.

A brief report of the five cases in which operations were done by this method follows:

REPORT OF CASES

CASE 1.—J. F. C., a white man, aged 58, had an umbilical hernia of small size for several years; this had gradually been getting larger and when there was any digestive disturbance he had pain in the region of the hernia. Because of these factors operation was advised, which was performed at Union Memorial Hospital, Feb. 3, 1925. The operation as described in the text of this article was performed with the use of relaxation incisions in the anterior rectus sheath. The patient made an uneventful recovery, the wound healing by first intention. Since that time he has traveled extensively abroad, played golf, and engaged in the usual activities of a physician's life with no trouble whatever. Several subsequent examinations at intervals of two or three months apart showed a solid repair with no weak spots. It is impossible to tell by palpation where the relaxation incisions were made in the anterior sheath. The abdominal wall is uniformly strong.

CASE 2.—W. B., a white woman, aged 54, had a large umbilical hernia for a number of years which became more noticeable after the birth of a child and increased gradually in size. At the time of operation when the patient coughed and strained a mass about the size of a large grapefruit protruded. An operation was performed, May 8, 1925, at Johns Hopkins Hospital, the method used being that described in the text of this article, without the use of relaxation incisions, as there was so much slackness of the abdominal wall that the sutures could easily be placed and tied without the need of the additional incision. The patient's convalescence was uneventful; the wound healed by first intention, and she has returned to her ordinary duties as a housewife. Subsequent examinations after the passage of two or three months showed a solid abdominal wall with no points of weakness.

CASE 3.—C. M., a colored man, aged 26, an iron worker in a structural steel mill employed in heavy manual labor, had a small umbilical hernia about 2 cm. in diameter which protruded when he coughed or made any straining effort, and caused him pain on these occasions. An operation was performed at Johns Hopkins Hospital, June 30, 1925, by the method described here with the use of the relaxation incision in the anterior sheath. The patient made an uneventful convalescence, and the wound healed by first intention. The patient returned after three weeks' convalescence at home and about five and a half weeks following operation to his previous occupation. He has been engaged in hard physical work. Subsequent examinations at intervals of two or three months showed a perfectly solid abdominal wall; there are no points of weakness, and although this patient is thin one cannot feel the incision in the anterior sheath.

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1. Personal communication to the author concerning work soon to be published.

Patients 2 and 3 were in the general surgical service of the Johns Hopkins Hospital and I am indebted to Dr. Frederick Reichert for allowing me to operate on them.

CASE 4.—P. S., a white woman, had had an increasing umbilical hernia for a number of years which had become quite large and was comparable in size to that in Case 2. An operation was performed, July 11, 1925, at Johns Hopkins Hospital by the method described in this article without the use of the relaxation incision. Convalescence was uneventful, and the wound healed by first intention. The patient returned to her duties as housewife and an examination made two months after operation showed a solidly healed abdominal wall with no signs of weakness.

This patient was in the gynecologic service of the Johns Hopkins Hospital and I am indebted to Dr. Telinde, late resident on that service, for permitting me to operate on the patient.

CASE 5.—S. E., a white woman, aged 51, had an umbilical hernia since childhood which had remained small and given no trouble until about two years before admission, when, while lifting, the patient noticed pain in the hernia. Since that time the hernia had enlarged until it was about 6 cm. in transverse diameter. July 28, 1925, the hernia became strangulated and the patient required morphin before it could be reduced. An operation was performed, Aug. 4, 1925, at Union Memorial Hospital, by the method described in this article without the relaxation incision. It may be noted here that the other two women patients were notably obese but that this patient was exceptionally fat, weighing nearly 300 pounds (136.1 kg.). This fat in no way interfered with the performing of the operation. The patient made an uneventful recovery, and the wound healed by first intention. She was discharged from the hospital twenty days after the operation in good condition. She returned to her usual duties and subsequent examination made about four weeks after her discharge from the hospital showed a solidly healed wound with no weakness in the abdominal wall.

For the privilege of operating in this case I am indebted to Dr. John E. King, resident at the Union Memorial Hospital.

In conclusion, while repeating that experience with this operation has been limited as to number of cases and is short in duration of time, the method is published because it is believed to remedy a weakness in the present generally practiced surgical repair of umbilical hernias, and in the hope that further test may be made of its value.

COXA VARA *

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AND
EMIL D. HAUSER, M.D.
ROCHESTER, MINN.

Coxa vara is an anatomic term introduced by Müller,[1] who applied it to those cases in which there was adduction of the distal part of the lower limb toward the sagittal plane of the body, caused by a lowering of the femoral head. Müller [1] considered the condition analogous to pes varus. Later, Kocher [2] wished to reserve the term coxa vara for the adolescent type only, a type associated with external rotation and whose etiology is uncertain, and for that of known etiology he introduced the term coxa adducta. This distinction, however, was not generally accepted, and the term coxa vara is now used in a wide sense to include all cases in which there is a diminution in the angle formed by the neck and the shaft of the femur, whether or not it is associated with external rotation.

REVIEW OF THE LITERATURE

Isolated cases of coxa vara were described by Röser [3] in 1843, by Zeis [4] in 1851, and by Richardson [5] in 1857. In 1881 Fiorani [6] described a group of fifteen cases in which there was bending of the femoral neck and which were probably of rachitic origin; in several of the cases there was no limitation of motion at the hip, and therefore a mistaken diagnosis is probably indicated. Nothing further was heard concerning this disease until 1888, when Müller [1] drew attention to this insufficiently described deformity and showed that there was a relationship between the clinical syndrome and the incurvation of the neck of the femur. He

* From the Section on Orthopedics, Division of Surgery, Mayo Clinic.

1. Müller, Ernst: Ueber die Verbiegung des Schenkelhalses im Wachsthumsalter, Beitr. z. klin. Chir. **2**:1, 1888; abstr. by Garré, in: Zentralbl. f. Chir. **16**:266-267, 1889; Zur Frage der Schenkelhalsverbiegung, Zentalbl. f. Chir. **21**: 817-820, 1894; Zur Coxa vara, Deutsch. Ztschr. f. Chir. **42**:505-508, 1896.

2. Kocher, T.: Ueber Coxa vara, eine Berufskrankheit der Wachsthumsperiode, Deutsch. Ztschr. f. Chir. **38**:521-548, 1894; Zur Coxa vara, Deutsch. Ztschr. f. Chir. **40**:411-425, 1895.

3. Röser: Ueber Morbus coxarius (Luxatio spontanea), Med. Cor.-Bl. d. württemb. ärztl. Ver. **13**:193-197, 1843.

4. Zeis, E.: Beiträge zur pathologischen Anatomie und zur Anatomie des Hüftgelenkes, Breslau, 1851, pp. 231-290.

5. Richardson, quoted by Tubby, A. H.: Deformities, Including Diseases of the Bone and Joints, London, Macmillan Company, 1912, **1**:578.

6. Fiorani: Sopra una forma speciale di zoppicamento, Gazz. d. osp. **16-17**, 1881; abstr. by Kölliker, in: Zentralbl. f. Chir. **9**:265-266, 1882.

described four cases in which the ages of the patients varied between 14 and 18 years. A resection was performed in one case to relieve pain, and the joint, as well as the surrounding tissues, was found to be normal, the pathologic changes affecting the neck alone. Ziegler, who examined the specimen removed microscopically, found no specific change except the softening process in the neck, which might be described as osteomalacia, osteitis deformans or osteomyelitis. Taking into consideration the clinical and pathologic findings, Müller [1] considered the condition analogous to knock-knee, and concluded that the bending of the femoral neck was a static deformity of rickets, although no demonstrable lesion of rickets was found elsewhere in the body. Immediately prior to 1888, Keetley [7] described a case, and in 1890 he successfully performed a subtrochanteric osteotomy to correct the deformity.

The next landmark in the history of coxa vara is a paper by Kocher in 1894,[2] although in the interval many cases had been reported in the European literature. Kocher's paper was based on three adolescent cases, those of a young farmer and two cheese makers. Resection of the entire head and neck was performed in the first case because of a condition which he described as adhesive arthritis. The findings at operation and the resected specimen cleared up the diagnostic error; the femoral neck was peculiarly deformed, the upper border was lengthened, the head appeared to be turned downward and backward, and the neck rotated on a longitudinal axis, forming a triple deformity. Langerhans studied this case microscopically, but nothing definite was found, and rickets was again assumed to be the etiologic factor. Kocher believed it was due to a peculiar kind of strain. In the case of cheese makers, he emphasized the strain on their hips brought about by holding the milk pails between their knees. They spread their legs and rotated them outward in order not to spill the milk. The muscles became tired and a strain was put on the iliofemoral ligament, from which, so to speak, the pelvis is suspended. The weight of the body, as well as that of the milk, came directly on the head and neck of the femur. This strain on the adolescent for several hours each day seemed to Kocher a satisfactory explanation, but it is scarcely permissible to speak of occupation as the direct factor of etiology on a basis of two cases, especially as there are hundreds of cheese makers without coxa vara.

After the appearance of Kocher's paper, controversy arose as to who originally described the deformity, but Müller most probably was the first to describe the association of the incurvation of the neck with the clinical findings we now know as coxa vara, although Kocher undoubtedly added quite appreciably to both his pathologic and clinical descrip-

7. Keetley, C. B.: Coxa Vara, Lancet **1**:775; 1115-1118, 1900.

tions. Hofmeister,[8] in 1894, brought out the relative frequency of this deformity, and pointed out that it is a rare disease and should be excluded in all hip conditions. He believed the condition to be due to a disturbance between static strain and resistance of the bone. Soon after Kocher's paper, numerous articles appeared in the literature pointing out the relationship between adolescent coxa vara and trauma. Sprengel[9] and Poland[10] showed that incomplete separation of the epiphysis was sufficient to cause the condition leading to coxa vara, and still later Joachimsthal,[11] Tubby,[12] and Whitman[13] showed that a static coxa vara could arrive spontaneously.

Lorenz,[14] in 1909, expressed the view that there was no such thing as idiopathic coxa vara but that in every case there was a contusion of a more or less severe nature. He is supported by Sprengel,[9] Rammstedt,[15] Kempf[16] and others, all of whom hold that coxa vara is a lesion at the epiphysis which has resulted from union in an abnormal position of a separated epiphysis.

By those writers who assume that load is the main factor and that there is no associated disease, various adjectives have been introduced to describe the condition, such as static, essential, adolescent and idiopathic.

The congenital type of coxa vara has a more recent history. In 1896 Kredel[17] described two cases as congenital coxa vara, and soon after-

8. Hofmeister, F.: Zur Pathologie und Therapie der Coxa vara, Beitr. z. klin. Chir. **21**:299-364, 1898.

9. Sprengel: Ueber die traumatische Lösung, der Kopf-epiphyse des Femurs und ihre Verhältniss zur Coxa vara, Arch. f. klin. Chir. **57**:805-840, 1898; Ueber einen operirten und einen nicht operirten Fall von Coxa vara traumatica, Arch. f. klin. Chir. **59**:937-947, 1899.

10. Poland, John: Traumatic Separation of the Epiphyses, London, Smith, Elder & Co., 1898.

11. Joachimsthal, G.: Die angeborenen Verbildungen der unteren Extremitäten, Fortschr. a. d. Geb. d. Röntgenstrahlen **8**:-8-13, 1902; Ueber Coxa vara-Bildung nach Reposition der angeborenen Hüftverrenkung, München. med. Wchnschr. **1**:641-643, 1909.

12. Tubby, A. H.: Deformities, Including Diseases of the Bone and Joints, Ed. 2, London, Macmillan Company, 1912.

13. Whitman, Royal: Further Observations on Coxa Vara, New York M. J. **69**:73-81, 1899.

14. Lorenz, A.: Ueber die ambulante Behandlung des Schenkelhalsbruches in extremer Abduktion und leichter Einwärtsrollung, 81 Versammlung deutscher Naturforscher und Aerzte in Salzburg, Zentralbl. f. Chir. **38**:1664-1665, 1909.

15. Rammstedt, Conrad: Ueber traumatische Lösung der Femurkopf-epiphyse und ihre Folgeerscheinungen, Arch. f. klin. Chir. **61**:559-583, 1900.

16. Kempf, Friedrich: Principielles über Begriff, Aetiologie und Therapie der Coxa vara, Arch. f. klin. Chir. **85**:784-826, 1908.

17. Kredel, L.: Coxa vara congenita, Zentralbl. f. Chir. **23**:969-973, 1896.

ward Zehnder,[18] Mouchet and Ségard [19] also reported cases. These cases were described before roentgen rays were in use, and no operative intervention was carried out; consequently, there is just a little doubt as to the true nature of these cases. Some time later Alsberg [20] criticized the cases; he regarded congenital coxa vara as associated with one of two conditions, either congenital dislocation of the hip or a congenital anomaly in some other part of the body. Following Alsberg's paper, a publication appeared by Kirmisson [21] who ascribed the deformity to a contraction of the posterior part of the capsule.

The most valuable of the early papers on congenital coxa vara is that by Hoffa,[22] published in 1905. He described two cases undoubtedly congenital in origin, and his views were supported by roentgenograms and by a resected specimen. This was the first clinical, pathologic and anatomic picture of congenital coxa vara. Numerous papers have since appeared, and today the field is a large one.

CLASSIFICATION OF COXA VARA

In all diseases in which many varieties exist, classifications are numerous; coxa vara is no exception to this rule. The classifications of coxa vara have been considered from several different standpoints. Pathologic anatomy has served as a basis for some of them, one of which, based on the site of bending in the neck, includes three groups: epiphyseal, mediocervical and trochanteric. Etiology has served as the basis of another classification, the various types being classed as tuberculous, osteomyelitic, infectious, neoplastic, and so forth. Another and more simple method was to divide them into two great types, congenital and acquired. The last method will form the basis of our classification, each of the two great types being subdivided into several subtypes.

Congenital Type.—This type of coxa vara is intimately associated with hypoplasia of the head and neck of the femur, and includes all varieties of defects appearing at birth or any time up to the fourth year of life. At the end of four years complete ossification of the neck takes place, and no further congenital defect is possible. The defects range

18. Zehnder: Ueber Schenkelhalsverbiegung, Zentralbl. f. Chir. **24**:241-248, 1897.

19. Mouchet, A., and Ségard, M.: La coxa vara congénitale, Paris méd. **5**: 421-425, 1912.

20. Alsberg, A.: Anatomische und klinische Betrachtungen über Coxa vara, Ztschr. f. orthop. Chir. **6**:106-172, 1898.

21. Kirmisson, E.: Nouveaux faits pour servir à l'étude de l'incurvation rachitique du col fémoral; coxa vara d'origine congénitale, Rev. d'orthop. **8**: 302-313, 1897.

22. Hoffa, A.: Die angeborene Coxa vara, Deutsch. med. Wchnschr. **2**:1257-1260, 1905.

from an apparently normal head and neck at birth to segmentation of the entire femur, and may be grouped as follows:

1. At birth the head is in the acetabulum and in roentgenograms appears normal, but as growth proceeds the head is slow in uniting with the shaft and a pseudarthrosis is produced. The symptoms of this type may appear any time up to the fourth year.

2. The femur is diminished in length and thickness but is not deformed, and there exists a congenital coxa vara. This type is generally associated with other congenital anomalies, such as dislocation of the hip, absence of the tibia, asymmetry of the pelvis, or club-hands and feet.

3. There is a hypoplasia of the superior extremity of the femur, the inferior extremity being apparently normal. In roentgenograms taken during the first and second years of life, the head appears to be entirely absent, and clinically the head resembles that in congenital dislocation of the hip. Roentgenograms taken two or three years later show that the head is slowly ossifying. It never attains complete ossification, however.

4. In this type the hypoplasia is much greater than in the acquired. The femur is separated into several distinct segments, which may consist of the lower diaphysis with its epiphysis, the head and trochanter, and the remaining portion of the diaphysis. The foregoing is based on the classifications of Reiner,[23] Drehmann,[24] Helbing [25] and Meyer,[26] but has been modified to conform to our group of cases.

An infantile type of coxa vara has been described by Hofmeister [8] and Elmslie,[27] according to whom the symptoms come on any time up to the fourth year of life and are generally associated with the so-called fissure neck, or pseudarthrosis. This appears to be but one group of Type 1 in which nature has failed to ossify the neck completely.

Acquired Type.—Two types seem to crystallize from the study of this group: Type 1, of unknown or at least uncertain etiology, which has been described as static, adolescent, essential, and so forth, and

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23. Reiner, M.: Ueber die unblutig operative Epiphyseolyse zur Behandlung des Genu valgum adolescentium, Ztschr. f. orthop. Chir. **11**:241-272, 1902-1903; Ueber die Beziehungen von congenitaler Coxa vara und congenitalem Femurdefect, Berl. klin. Wchnschr. **40**:614-616, 1903.

24. Drehmann, G.: Zur Frage der angeborenen Coxa vara, Berl. klin. Wchnschr. **2**:1752-1753, 1910; Die Coxa vara und ihre Behandlung, Ztschr. f. orthop. Chir. **45**:421-431, 1924.

25. Helbing, Carl: Ueber congenitale Schenkelhalsfissur, Deutsch. med. Wchnschr. **28**:259-261, 1902.

26. Meyer, H.: Das Verhalten der Epiphysenlinie bei der Coxa vara, Arch. f. Orthop. u. Unfallchir. **18**:403-418, 1920.

27. Elmslie, R. C.: Injury and Deformity of the Epiphysis of the Head of the Femur, Coxa Vara, Lancet **1**:410-417, 1907.

appears to have a relationship to trauma, occupation, and to the internal secretion of the hypophysis cerebri; and Type 2, with a definitely known etiology, which has been classified variously as infectious, osteomyelitic, tuberculous, neoplastic (including cystic), traumatic and neuropathic. The latter type, which is by far the larger, will not be discussed.

ANATOMIC CONSIDERATIONS

In order to appreciate the various changes that take place in the neck of the femur, it is necessary to have a clear understanding of the development of the upper end of that bone. At birth the upper end of the femur consists of a mass of cartilage separated from the shaft by a more or less transverse line of ossification. As growth proceeds, this transverse line of ossification gradually rises until at the end of the fourth year of life it comes in contact with the upper margin of the neck and separates the epiphysis of the head from that of the great trochanter (Fig. 1). The head of the femur is developed from a single ossific nucleus which appears from ten to twelve months after birth. As it develops, it passes upward and inward from the growth of the neck, while the great trochanter passes upward in the line of the shaft. The epiphyseal head is hollow and hemispherical in shape, and by the end of the sixth year is almost entirely osseous. The superior epiphysis of the femur is situated entirely within the capsule of the hip joint and is completely surrounded by synovial membrane, although it is possible to detach it without opening into the joint cavity, since the synovial membrane and the capsule can be stripped the entire distance from the neck of the bone to the head, leaving the joint intact. Actual detachment of the head cannot occur until the fourth year as the neck is not completely ossified and consequently the head is not a separate epiphysis until then. Epiphyseal separations during the first four years have been described, but they would be more correctly called separations of the upper end of the femur. Separation of the epiphysis occurs most frequently between the ages of 14 and 18 years, and the separation takes place on the diaphyseal side of the epiphysis, the epiphyseal line remaining attached to the head.[10]

The end of the fourth year of life also marks the latest time of onset of the congenital type of coxa vara, for at that age the neck becomes completely ossified and any risk of a hypoplasia has disappeared.

The upper end of the femur is twisted anteriorly to the condyles, producing an angle on the average of 12 degrees with a variation of from 5 to 40 degrees, except in a very small percentage of femurs, in which the twist is absent. This twist is known as the torsion angle or angle of declination, and may be defined as the angle between the diaphyseal axis of the femur in a condylar plane and the axis of the

neck. This condition appears to come on gradually; it does not begin until the fourth month of fetal life, but during the fifth and sixth months of fetal life the maximal angle of declination, from 22 to 33 degrees, is reached. This angle is retained until the subject is 2½ years of age, when diminished torsion gradually takes place by a retroversion of the neck, until an average of 12 degrees is reached. It is difficult to understand why this reduction in antetorsion should take place; possibly as the child assumes the erect posture, the iliofemoral ligaments may have an important retroverting action, as well as the external rotator muscles, which are much more powerful than their opponents, the internal rotators. It is difficult to measure clinically the angle of torsion, although it is easily done on the skeleton. Drehmann [24] has suggested a method of measuring it by roentgen rays. He takes one picture in a median position and one with the leg rotated internally until the trochanter major

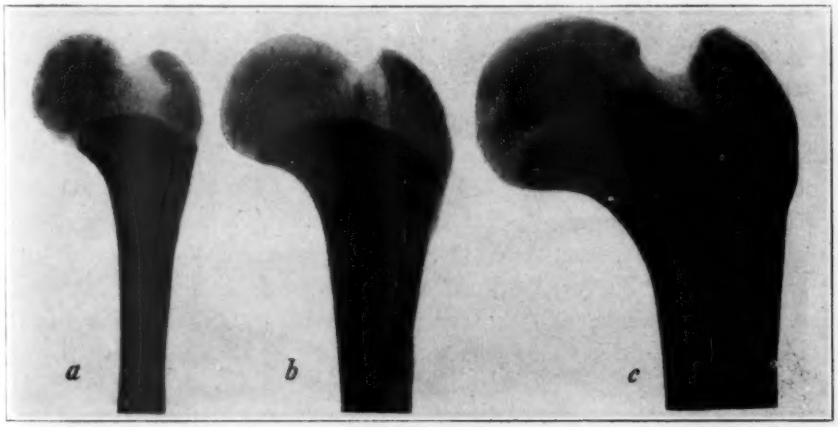

Fig. 1.—Upper end of femur of a child; *a*, at birth; *b*, at the age of 2 years, and *c*, at the age of 3 years. (After Lange and Spitzy.)

points outward. The degree of inward rotation of the foot in the latter position gives the degree of antetorsion. The margin of error by this method is considerable, between 15 and 20 degrees. Other methods have been described, but they are more complicated and equally inaccurate.

The bone lamellae in the neck of the femur are arranged in two very definite systems called the compression and traction arches. The system in the upper part of the neck is known as the traction arch and that in the lower part as the compression arch. The lamellae on the traction arch run not only in a frontal plane, but also in an oblique frontal plane from the front downward and backward. These arches therefore give sustaining power to the femur and prevent the neck from bending downward and backward. Since the bending of the neck in coxa vara is

downward and backward and takes place where the stress is greatest, Sudeck [28] assumes that this is an expression of insufficiency of the traction arch system.

In a certain proportion of cases, a visible ridge of bone appears at puberty on the upper part of the neck of the femur and runs around the middle of that portion of the bone (Fig. 2). This ridge corresponds to the top of the traction arch system. Several views are held regarding its appearance and function. Sudeck regards it as an important factor in strengthening the traction arch, and as it appears at puberty it may also have some influence in reinforcing the epiphysis. Bähr,[29] who has also investigated this subject, does not believe that it has any influence in strengthening the traction arch nor that its situation is at the height of the arch. He is of the opinion that it is due to the attachment of the capsule at this point on the neck. Still other writers suggest that it is due to the attachment of the synovial membrane. Bähr's view seems the most reasonable, but whatever view is held regarding its function, the fact remains that it is a much stronger ridge and almost invariably appears in coxa vara.

The sign now generally associated with the name of Trendelenburg was first described by Duchenne of Boulogne in 1867. He stated that it occurred in cases of infantile paralysis in which there was weakness or paralysis of the gluteus medius and minimus muscles. Trendelenburg later pointed out its occurrence in cases of congenital dislocation of the hip, and later still Alsberg [20] said that it occurred in certain cases of coxa vara. This phenomenon is absent if the patient stands on the sound leg and raises the affected leg with the knee bent, at the same time raising the pelvis slightly on that side, but it is present if he stands on the affected leg and raises the normal one, lowering the healthy half of the pelvis, and at the same time throws his body toward the side on which he is standing. With the weight on the healthy side all the gluteal muscles are under tension, the gluteus maximus probably being the chief actor and causing tension on the iliofemoral ligament. The center of gravity is shifted a little toward the side of the normal leg by leaning slightly toward that side; this involves contraction of the gluteus medius and minimus and causes still further tension on the iliofemoral ligament. A positive phenomenon may be obtained by alteration in the iliofemoral ligament, or in the head and neck of the femur or gluteal muscles. The iliofemoral ligament is one of the most powerful ligaments in the body and extends from the antero-inferior spine to the anterior trochanteric

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28. Sudeck, Paul: Zur Anatomie und Aetiologie der Coxa vara adolescentium, Arch. f. klin. Chir. **59**:504-524, 1899.

29. Bähr, F.: Zur Lehre von der Coxa vara, Arch. f. klin. Chir. **61**:533-541, 1900.

line. If this ligament is relaxed or cut, the pelvis falls toward the raised side without any further load; similarly, if the entrance to the pelvis is tilted, a positive phenomenon is seen. A normal person can produce this phenomenon, as pointed out by Kehl,[30] by flexing the hip and at the same time maintaining the erect posture causing a lumbar

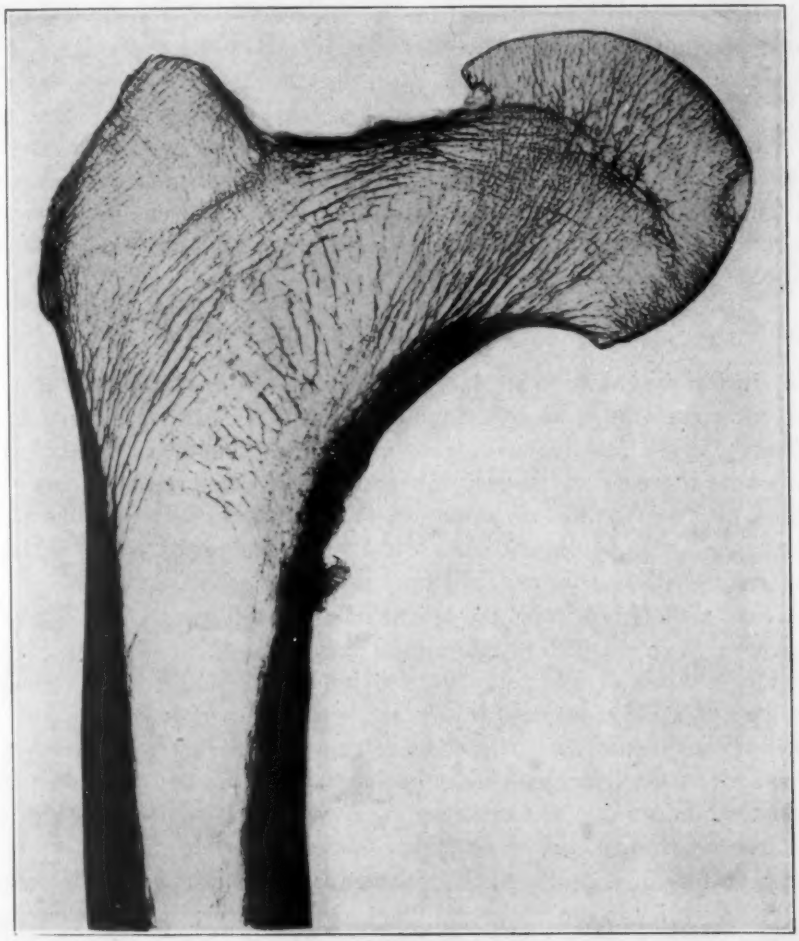

Fig. 2.—Lines of stress in upper end of femur; the enlarged tubercle on the upper border of the femoral neck is seen at the summit of the traction arch. (After Sudeck.)

lordosis; the iliofemoral ligament is thus relaxed. If the ligament is again tightened by action of the gluteus maximus, the horizontal position of the pelvis will be obtained. Bony changes in the region of the hip

30. Kehl, H.: Die Anatomie des Trendelenburgschen Phänomens am Hüftgelenk, München. med. Wchnschr. **1**:776-777 (June 13) 1924.

joint also induce a positive sign. These bony changes lead to a definite decrease in the distance between the attachments of the iliofemoral ligament. The conditions in which the Trendelenburg sign is commonly seen are: congenital dislocation of the hip, coxa vara, osteochondritis deformans juvenalis, fracture of the neck of the femur and arthritis, in all of which the relationship between the iliofemoral ligament and the gluteus maximus is altered and the gluteus medius and minimus are not in a position to maintain the horizontal position of the pelvis. The presence of this phenomenon is dependent on the extent of the deformity, being absent in the earlier and less marked cases, but invariably present in the advanced cases. Changes in the gluteal muscles themselves will also lead to a positive sign, as in progressive muscular atrophy, infantile paralysis and flexional deformity of the hip, and, similarly, if the great trochanter approaches the crest of the ilium, the smaller gluteal muscles will work at a disadvantage and produce the phenomenon.

ANALYSIS OF CASES

During the twelve years from 1912 to 1924, fifty-eight cases of adolescent coxa vara and seventeen of congenital coxa vara have been observed in the Mayo Clinic. Of the fifty-eight adolescent cases, forty-two were in males and sixteen in females. Of the seventeen congenital cases, eleven were in males and six in females. The conditions were bilateral in nine adolescent cases and in three congenital cases. Males therefore predominate, and unilateral affections are the rule.

In the adolescent type, the age at onset varied from 11 to 18 years. A curve (Fig. 3) plotted to indicate the incidence at different stages rapidly attains its maximum at the fourteenth year, then gradually declines until the eighteenth year, after which no cases have been known to develop. Ten of the fifty-eight cases began at the fourteenth year. The ages at which the patients came for treatment varied from 11 to 49 years. Adults came for treatment because of the resulting deformity and the superimposition of arthritic changes in the hip joint.

A feature of considerable significance is the almost invariable occurrence of obesity in the adolescent type. In our series of cases there are accurate records of height and weight during the active phase of the disease in twenty-six boys and ten girls between the ages of 12 and 18 years. In normal persons of the same age, there is considerable variation in height and consequently in weight. Therefore, to compare satisfactorily the type of person suffering from adolescent coxa vara with the normal, a definite correlation between the height and weight at different ages is necessary.

Two curves were plotted (Figs. 4 and 5) to bring out this feature. In the first curve the weight of a patient was compared with the weight

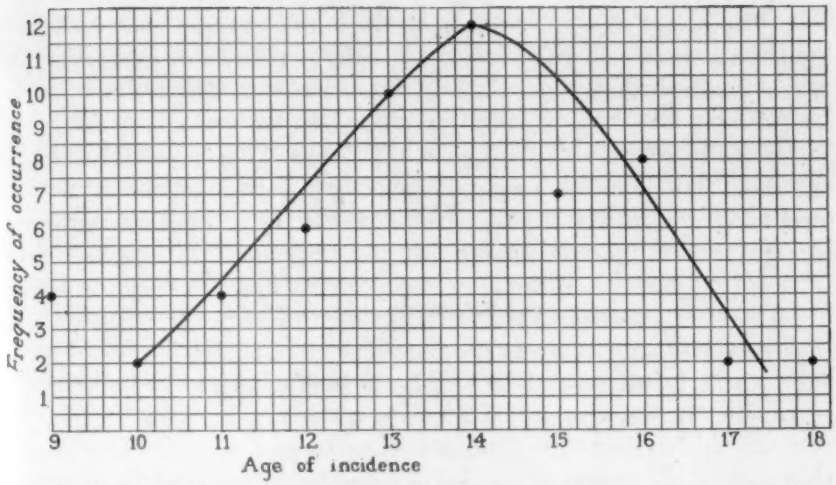

Fig. 3.—Incidence of adolescent coxa vara at different ages, the maximal frequency being at the age of 14 years.

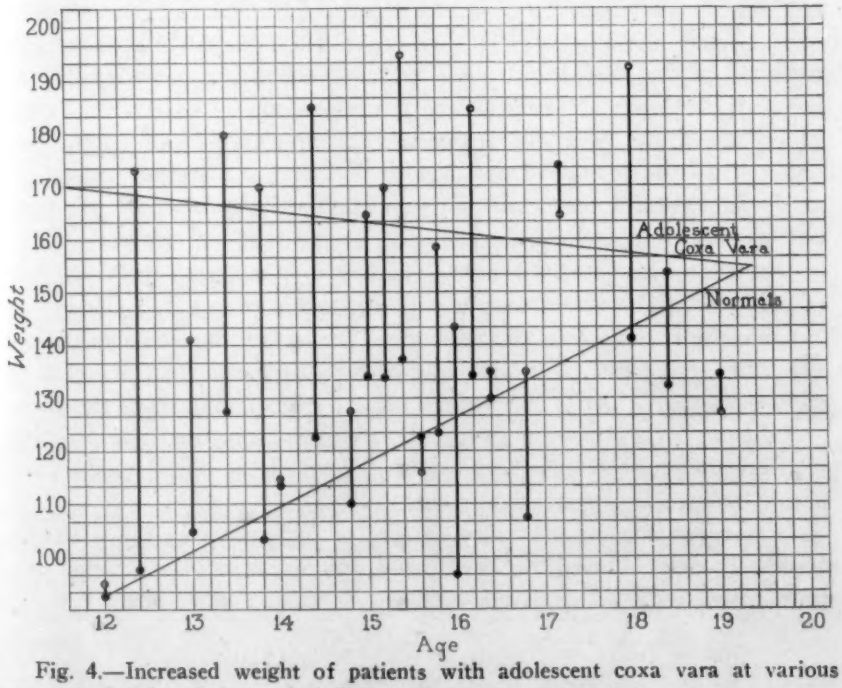

Fig. 4.—Increased weight of patients with adolescent coxa vara at various ages, the height of the patient being taken as a constant.

of a normal boy of the same age and of the same height for that age. The height and age being the same in both instances thus became a constant, so that the weights could be plotted, as shown in Figure 4. The heights and weights were obtained from the standard tables compiled by Baldwin and Wood.[31] In the second curve the height-weight, or ponderal, index was plotted against the age. The ponderal index is obtained by dividing the weight of the body in pounds by one-thousandth part of the height in inches. This index was worked out by Bardeen [32] and gives a more accurate curve than the other one. The type of curve obtained as compared with the normal ponderal index is shown in Figure 5. The curves obtained show certain distinct features common to both. The greatest variation from the normal is seen at the fourteenth year, the patients being most obese at this age, and showing the greatest disproportion between height and weight as compared with the normal. Also the incidence of the disease is greatest at this age. The general character of the curve shows that the greatest divergence from normal is at the twelfth year. Then it gradually approaches normal, which is attained at about the eighteenth or nineteenth year. Our series of ten girl patients with weights recorded were practically all between the ages of 13 and 14. All were obese but the average was slightly less than that for boys. There were two extremely tall and thin patients in this series, one a boy and the other a girl. The onset of the disease in both instances occurred at the seventeenth year, which brought the curve at that age below the average. The extremely tall patients form a very definite group which are susceptible to coxa vara, and may be called the giant type. This type is much rarer than the adipose, and appears to come on rather later in adolescence, displacement occurring slowly owing to weakness at the epiphysis from the excessive growth and activity at that point.

An examination of the curves clearly demonstrates the association of very marked excess of weight with adolescent coxa vara. This excessive weight is limited to the adolescent period, attains its maximum at the fourteenth year, then gradually returns to the normal at about the eighteenth year. The curves representing the age incidence of the disease and the ponderal index run practically parallel, indicating a very definite relationship between these two factors. Two of the obese male patients had a definite Fröhlich's syndrome.

A careful investigation into the factor of trauma in the fifty-eight adolescent cases showed that the disease was insidious in onset in twenty-four cases, with no available history of trauma whatsoever. In the

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31. Baldwin, B. T., and Wood, T. D.: Weight, Height, Age Table, New York, The American Public Health Association.

32. Bardeen, C. R.: The Height Weight Index, Contributions to Embryology, Carnegie Institute **46**:483, 1920.

remaining thirty-four cases, trauma of a greater or lesser degree had been sustained at the onset or at some time during the course of the disease. The latter cases may be divided into three groups.

In Group 1 (eighteen cases) the disease was insidious in onset and progressive for a time; the trauma sustained later was usually of a minor nature, and the rate of progress of the disease may or may not have been increased by it. Four of the patients gave occupational strain as the minor trauma. One was a milkman accustomed to jumping on and off his van many times a day, and the other three were farmers who were subjected to similar jars.

Group 2 consists of ten cases in which there were no symptoms previous to the accidents. In three of the ten cases there was a history of repeated minor trauma, and in the remaining seven a history of a definite

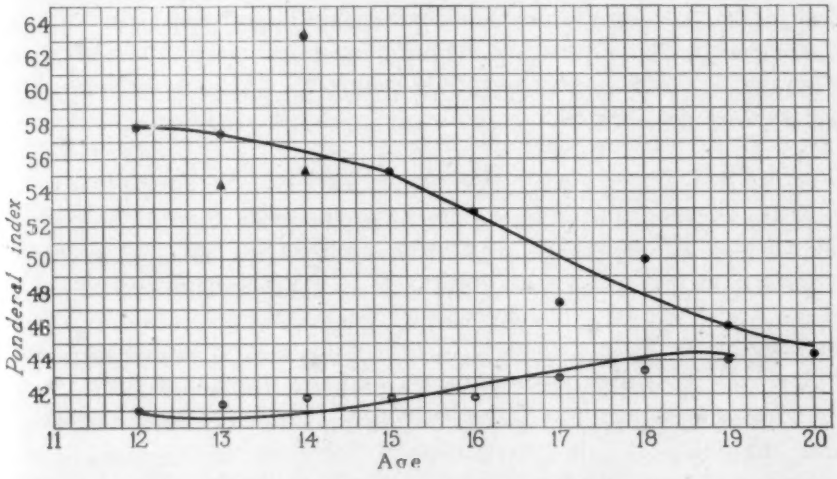

Fig. 5.—Ponderal index in the normal person and that in the adolescent with coxa vara.

trauma followed by an interval of a few weeks to a few months which was symptomless, then the gradual development of coxa vara. This group has many points in common with cases of acute bony atrophy, or that condition known as Kümmell's disease of the spine; the initial trauma may cause atrophy of the bone with increased friability of the epiphysis, the superimposed weight of the body causing a slow displacement at that point.

Group 3 includes six cases which have a more definite relationship to trauma than the two previous groups. The onset followed immediately on a definite injury which, although not sufficient to incapacitate the patient, was usually more severe than in the other groups, and the patient in many cases had to go to bed for a few days. The symptoms persisted

in a minor degree and coxa vara slowly developed. There is no evidence to show that any displacement took place at the time of the injury.

Our inference from the analysis of these cases is that trauma plays a very minor part in the etiology of this disease, and that the disease is a constitutional one depending on glandular deficiency.

The seventeen cases of congenital coxa vara included fourteen cases of the mildest degree associated with fissure of the neck, the symptoms appearing at variable times between birth and the completion of the fourth year: one case with complete absence of the head and neck of the femur, one case associated with congenital absence of the clavicles, and one case associated with congenital dislocation of the hip and congenital club-hands and feet.

The Wassermann reaction in thirty-five cases was negative, and the Pirquet test was applied in seven cases with negative reactions in all except one, in which the reaction was but faintly positive. The calcium and inorganic phosphorus was estimated in five cases of the adolescent type, but the variations from normal were very slight and nothing conclusive could be deduced.

THEORIES OF CAUSATION OF ADOLESCENT COXA VARA

Various theories have from time to time been put forward to explain the etiology of adolescent coxa vara, each having many supporters, which means that there is uncertainty as to the true nature of this disease. They may be considered under four headings: (1) the osteomalacia, or late rickets, theory; (2) the traumatic, or continuous slipping, theory; (3) the endocrine theory, and (4) the static theory.

Osteomalacia, or Late Rickets, Theory.—This theory has many advocates, including Mikulicz,[33] Fromme,[34] Haedke,[35] Kocher[2] and Hofmeister,[8] and was the one advanced originally by Müller after operative intervention and pathologic study of a specimen removed in a case of coxa vara. That there is a softening of the epiphysis cannot be denied, and the older authors merely concluded that the softening must be due to late rickets or osteomalacia in spite of the fact that no other part of the skeleton showed any signs of it. Intermingled with the softening processes are static effects due to overweight, and the effects of trauma of varying degrees. Microscopic study of the disease gives no clue to the etiology, as the changes are not characteristic of any disease in particular.

33. Mikulicz, J.: Die seitlichen Verkrümmungen am Knie und deren Heilungsmethoden, Arch. f. klin. Chir. **23**:561-629, 1879.

34. Fromme, Albert: Die Spätrachitis und ihre Beziehungen zu chirurgischen Erkrankungen, Beitr. z. klin. Chir. **118**:493-545, 1920.

35. Haedke, M.: Zur Aetiologie der Coxa vara, Deutsch. Ztschr. f. Chir. **66**:89-96, 1902.

Traumatic Theory.—This theory has an equal number of supporters: Sprengel,[9] Kempf,[16] Rammstedt,[15] Schlesinger,[36] Fittig,[37] Lorenz [14] and others. As in the first theory, a special fragility of the upper epiphysis of the femur is often described, as the trauma in many cases is of quite a minor nature; against the purely traumatic origin is the fact that the disease sometimes occurs in both hips. The bilateral cases arouse the suspicion of a constitutional disease arising especially during puberty. On the other hand, in many cases there has been a succession of minor traumas, and it is not impossible that the first injury may lead to a softening of the epiphysis and the succeeding ones to the gradual separation of that epiphysis. Sudeck [28] has suggested that this disease may closely resemble Kümmell's disease of the spine, the primary injury setting up the condition of acute bony atrophy, and the succeeding injuries, or even weight-bearing too soon after the accident, causing the displacement. Kredel [38] believes that the term traumatic coxa vara should be limited to those cases in which a fracture of the neck or epiphyseal separation has occurred as the result of trauma in a normal hip, or in which the deformity occurs in a normal hip some time after trauma, as in Kümmell's disease.

Considerable experimental work has been carried out with regard to separation of the upper epiphysis of the femur. Poland [10] and Rammstedt [15] experimented on the cadaver, subjecting the hip joint to severe trauma in various positions, such as simple abduction, abduction and internal rotation, and extension and abduction. The unanimous opinion was that it is almost impossible to separate the epiphysis in any of these positions, no matter how severe the trauma. Rammstedt was unable to separate it by any of these methods until he dissected down to the hip and applied force directly to it. These writers believe that the epiphyseal disk must have undergone softening before the separation could take place, but also that trauma can produce this softening, and that the subsequent displacement, which is gradual and progressive, takes place owing to static conditions or succeeding trauma.

Static Theory.—This theory originally was announced by Kocher, and still has advocates in Frangenheim [39] and Drehmann.[24] Kocher, in

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36. Schlesinger, A.: Zur Aetiologie und pathologischen Anatomie der Coxa vara, Arch. f. klin. Chir. **75**:629-642, 1905.

37. Fittig, Otto: Die Epiphysenlösung des Schenkelhalses und ihre Folgen, Arch. f. klin. Chir. **89**:912-948, 1909.

38. Kredel, L.: Zusammenhang von Trauma, Epiphysenlösung und Coxa vara, Deutsch. Ztschr. f. Chir. **54**:161-166, 1900.

39. Frangenheim, Paul: Zur Pathologie der Osteoarthritis deformans juvenilis der Hüftgelenks, über Coxa vara und traumatische Epiphysenlösung am oberen Femurende, Beitr. z. klin. Chir. **65**:19-53, 1909.

support of it, described a very small group of cheese makers, already noted in the review of the literature. He considered coxa vara to be purely an occupational disease and comparable to genu valgum and pes valgus. This theory has little to support it, and Kocher's cases were too few to be of much value.

Endocrine Theory.—This theory has become more popular of recent years, and considerable evidence in favor of it has accumulated. It is now recognized that the pituitary type of person is more prone to coxa vara than the ordinary individual. This type of person has characteristics not unlike those of Fröhlich's syndrome, but of a minor degree, although many cases are recorded which occur as a complication of that syndrome. The association of Fröhlich's syndrome with hypopituitarism is now definitely established, although the functions of the entire pituitary body, as well as its individual lobes, are still a matter of controversy. The hypophysis is undoubtedly a regulator of growth and controls these processes at the epiphysis. The epiphyses seen in the roentgenograms appear more succulent and consequently are more fragile than in the normal subject. It is quite reasonable to assume that with the added weight in this type of person, the fragile epiphysis may give way from slight trauma or merely from static effects. The period between 10 and 12 years marks an increase in weight preceding a second period of growth between 12 and 15 years. If, during this second period, particularly marked changes due to growth take place at the epiphyseal line, the static resistance is temporarily reduced, and this indicates the period at which the disease is most common.

The mass of evidence supports the endocrine theory; the bilaterality, the special type of person, the occurrence of the disease without trauma, all point to it.

THEORIES OF CAUSATION OF CONGENITAL COXA VARA

From the simplest forms of congenital coxa vara to the apparent defect of the upper end of the femur, there appears to be a wide difference, but on analyzing the cases, the fundamental processes at work are the same, the only difference being in their extent. All gradations can be seen, from complete absence of the head and neck to a diminution of the angle of the neck with or without a fissure. In many cases there is in the first roentgenogram merely an outline of the head shadow, but in later roentgenograms ossification can be seen progressing in the neck, head and great trochanter.

There are many hypotheses to explain the causation of congenital coxa vara, although none has any great foundation in fact. Kredel attempts to explain it on the basis of lack of intra-uterine space, and

believes the neck fissure to be caused by intra-uterine pressure. Böhm [40] thinks it is a condition of atavism, and in support of this idea, points out that in anthropoid apes the neck is nearly at a right angle with the shaft of the femur. Hoffa [22] uses the term intra-uterine disuse of the bone of unknown etiology. Helbing [25] regards the condition as being due not only to a delay in bone formation, but to a direct lack of bone formation, with also a load on the limb which causes bending. Reiner [23] is of the opinion that the congenital defect of the femur originates from an embryonic vascular disturbance.

The theory of embryonic vascular disturbance appears to offer the best explanation of the disease. This vascular disturbance upsets the ossification of the neck and epiphyseal line, where vascular disturbance would be most deleterious. Depending on the extent of this disturbance, the result will be an intra-uterine coxa vara or a coxa vara which will appear only after weight bearing. Familial types of this disease have been described by Barrington-Ward [41] and Francke,[42] and these seem to support the theory of hypoplasia still further.

PATHOLOGIC ANATOMY

Adolescent Type.—The pathologic anatomy of the adolescent type of coxa vara will be discussed under two headings: changes in the neck of the femur and changes in other parts of the skeleton.

The description of the changes in the neck of the femur are based entirely on specimens removed at operation. Kocher's original specimens show that his resection was much more extensive than that performed now, for they include head, neck and great trochanter. They are valuable as pathologic specimens, and served as the basis of his original description.

The site of the displacement or bending is at the epiphysis, that is, at the juncture of the head and neck. Hofmeister suggests that the principal part of the curve is in the neck near the head and mainly at the line of the epiphysis, and that it is due to abnormal growth and proliferation of bone. We agree that the bending is very often at the epiphysis, but believe that it depends on the age and the period of growth. Hofmeister points out that there could be one bend, then further growth and increase in weight, and then another bend; thus in time a wedge with its base at the superior border of the neck would be inserted between the head and the diaphysis. The middle point of the base of this wedge

40. Böhm, Max, quoted by Nilsonne, H., in: Beitrag zur Kenntnis der kongenitalen Form der Coxa vara, Acta radiologica **3**:393, 1924.

41. Barrington-Ward, L. E.: Double Coxa Vara with other deformities Occurring in Brother and Sister, Lancet **1**:157-159, 1912.

42. Francke, quoted by Nilsonne, H., in: Acta radiologica **3**:388, 1924.

would be the maximal point of bending, and, depending on the size of the wedge, the further it would be from the epiphyseal line and the earlier the onset, the sharper the angle. This inserted wedge is not only above but also in front, and is important from the point of view of operative treatment as it clearly shows that the removal of two wedges is necessary to correct the deformity.

A ridge almost invariably appears on the upper border of the neck. This is occasionally seen in the normal femur, but is much more obvious in adolescent coxa vara. This ridge appears lateral to the epiphyseal line, and in adolescent coxa vara forms the apex of two sides of an inclined plane. Two explanations for this ridge have been suggested: one, that it is an osseous reinforcement at the point of weakness; the other, that it is the point of attachment of the capsule of the joint. The latter is the more probable explanation, as osseous reinforcements are not generally placed on the external aspect of bones.

Several factors play a part in the displacement of the head of the femur: superimposed weight, alterations in the epiphyseal line, muscle pull and trauma. The type of person with his increased weight together with the abnormal softening of the epiphysis are the chief factors in the downward displacement of the head, but the factors producing the incurvation of the neck and its twisting on a longitudinal axis are the iliofemoral ligament and the external rotator muscles of the thigh. The iliofemoral ligament fixes the leg in extension and offers considerable resistance to the external rotators of the thigh. When the attachments of this ligament are approximated by an upward movement of the great trochanter, hyperextension takes place; then the external rotators take over the mastery and produce external rotation of the leg as a whole.

This appears to be a satisfactory explanation of incurvation of the neck and rotation of the neck on a longitudinal axis, both of which are really secondary to the downward displacement of the head and elevation of the great trochanter. The chief deformity of the head and neck is, therefore, a triple one; it was accurately described by Kocher in his early resected specimens, and consists in downward displacement of the head with lengthening of the neck along its superior margin, anterior curvature of the neck and posterior twisting of the neck on its longitudinal axis.

Besides this deformity, there are several subsidiary ones. When viewed from the front the head of the femur appears distinctly oval, and in the roentgenogram, like a half moon. As the deformity progresses, the joint cartilage extends onto the upper part of the neck and disappears from the lower part of the head; this is the result of an attempt to obtain abduction. The appearance produced is that of a short neck, and in advanced cases the neck may even appear to be miss-

ing. On section the epiphyseal cartilage seems to be twice its normal breadth; the continuous line of the epiphysis is broken, and islands of gelatinous substance extend downward from the direction of the great trochanter to the under surface of the neck. The under surface of the head is atrophic, and as the deformity progresses the lower margin of the head approaches the shaft of the femur; in this way, the lower and the posterior parts of the neck are markedly shortened, but the length-

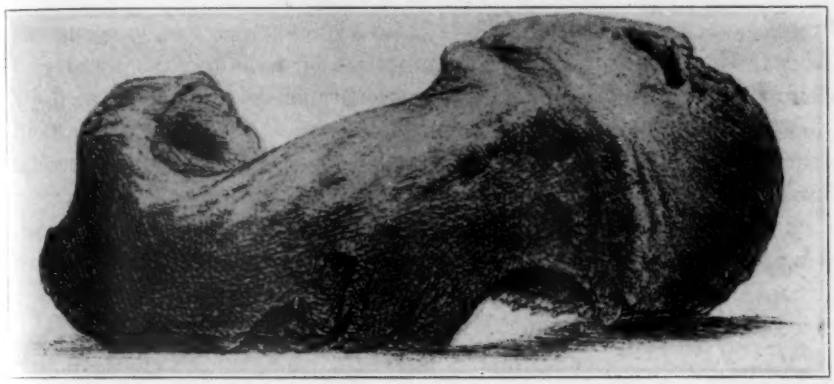

Fig. 6.—Anterior view of resected specimen of upper end of right femur, showing triple deformity. (After Kocher.)

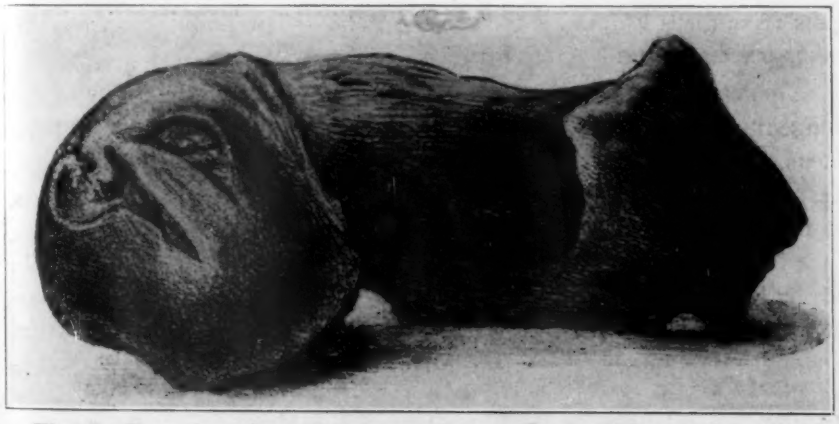

Fig. 7.—Posterior view of the same specimen as Figure 6, showing the triple deformity. (After Kocher.)

ening of the upper border of the neck is less marked than would be expected. During adolescence the actual joint cartilage is smooth, but as the patient matures secondary arthritic changes begin to appear in the hip joint. Coincidently, secondary and adaptive changes are noted in other parts of the skeleton: asymmetry of the pelvis, scoliosis, genu valgum flatfoot, and so forth (Figs. 6, 7, 8 and 9).

The microscopic picture of this disease is not well known, but there are certain modifications of architecture which are more or less constant and conform to Wolf's law. Absorption occurs in some places and formation of new bone in others, which are also probably secondary to pressure changes. The inferior and posterior aspects of the neck are reinforced by compact bone. The epiphyseal cartilage is enlarged, edematous in appearance, and more rich in cells and more strongly vascularized than normally. The distribution of the cartilage cells is irregular, not many of them being arranged in columns. In the spongiosa are islands of cartilage, some communicating with the epiphysis and others not; on the other hand, the cartilaginous zone is penetrated by osteoid tissue. Osteoclasts occur abundantly in areas where the osteoid tissue is replacing the cartilage. In other places normal bone may be found undergoing normal growth. The joint cartilage is much thicker in its upper part, and subchondral bone is often missing in the head, owing to atrophy of the spongiosa. In the upper part of the neck, where the capsule overlaps the head, it is difficult to determine where cartilage begins and connective tissue ends.

Coxa vara of the adolescent type runs a very definite course which can be divided into three distinct phases: the stage of softening, the stage of friability, and the stage of hardening. It is during the first and second stages that displacement and deformity take place, and this phase lasts from three to four years. In the stage of hardening, consolidation takes place and results in deformity if not treated.

Congenital Type.—The description of the pathologic anatomy of the congenital type of coxa vara was originally based on two resected specimens, one by Hoffa and one by Jones.[43] In most cases of this type, a fissure or break in the neck of the femur is apparent in roentgenograms, in resected specimens, and at operation. This fissure, or pseudarthrosis, as it is sometimes called, is vertical in direction and is disposed laterally to the normal epiphyseal line, which is horizontal at the age when congenital coxa vara occurs. This fissure is not always a straight vertical line, but may be like an inverted Y, which produces an irregular triangular piece of bone at the lower margin of the neck. In yet other cases, the fissure may be visible only in the upper part of the neck. This fissure looks like a fracture, and in such an event the coxa vara has occasionally been called traumatic. The edges of the fissure are at the same level and in apposition. Exploration at operation does not reveal spaces, but merely noncalcified osteoid tissue. The line of weight bearing is in line with this apparent infraction and at right angles to the epiphysis; consequently, the weight of the body will produce a slow and steady displace-

43. Jones, Robert, quoted by Elmslie, in: Lancet **1**:413, 1907.

ment of the head. The condition is progressive and the displacement increases until adult life is reached, when the head appears to come in contact with the lesser trochanter. The head is usually smaller than normal, or may even be absent; when present it is rotated downward

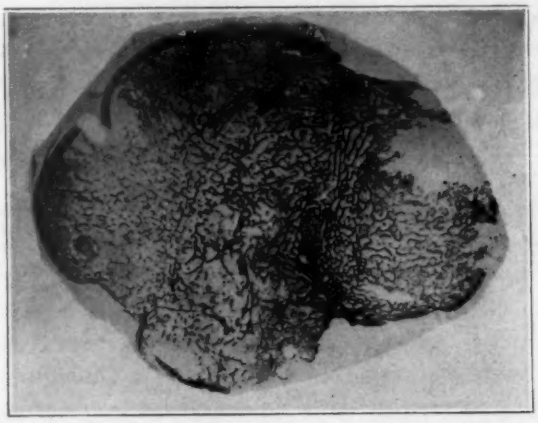

Fig. 8.—Section through the head of femur from a boy, aged 17, with bilateral coxa vara. The head of the femur had been resected because of secondary arthritic changes. The considerable irregularity of the epiphyseal line and the altered arrangement of the lamellae, with diminution of the cancellous bone, should be noted.

Fig. 9.—Low power photomicrograph of Figure 8, showing irregularity of the epiphysis with islands of cartilage lying in the spongiosa and areas of osteoid tissue in the epiphysis.

so that the lower margin is not in the acetabulum. There may be other pelvic defects, such as asymmetry of the pelvis or an abnormally narrow obturator foramen.

Various views are held regarding the etiology of this fissure in the neck. Hoffa looked on it as a broadened epiphyseal disk. Schanz [44] was later able to show that it did not correspond with the epiphyseal line, and that it separated the apparent head, which consisted of the actual epiphysis, and a fragment of the neck. Schwarz [45] regarded it as a cartilaginous neck disk and as a place of diminished resistance where displacement could take place. Drehmann considered it a femoral defect, a mild hypoplasia of the neck, probably vascular in origin. His view appears to be the most reasonable.

SYMPTOMS

As shown in our analysis of cases, two types of persons are susceptible to the adolescent type of coxa vara: the fat boy with occasionally a genuine Fröhlich's syndrome, and the young giant with weak epiphyses. The age at onset varies from 12 to 18 years, but usually for the fat type the age is 14 years, and for the young giants 17 years. This disease is much more common in boys than in girls, and is generally unilateral.

Adolescent Type.—In a large proportion of cases, one or more acute phases are seen during the course of the disease; some authors even state that during the course of the disease there is always a period in which there is increased pain associated with limitation or complete abolition of motion at the hip. The acute phase and the height of the pain are usually noted soon after the onset of the disease, and the patient may be forced to take to bed for a few days or even for a few weeks. The limitation of motion is due to muscle spasm; although the lesion is entirely extra-articular, it lies very close to the joint and in those cases with a period of rapid displacement there may be an effusion into the joint and temporary muscular rigidity. If the patient is seen for the first time during one of these acute phases, his case is likely to be diagnosed as tuberculosis or an acute infection of the hip joint.

Aside from the acute pain associated with muscle spasm, there is pain associated with physical work or trauma. This pain is not always pronounced; in some cases it may be slight, and in others there may be none. It appears to depend on the rapidity of the progress of the disease, and may be located in the hip itself, or in the back, or often in the knee. It may appear to start in the hip and run to the knee, or vice versa, and can often be elicited by pressure in the axis of the affected limb, or by pressure laterally on the great trochanters.

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44. Schanz, A.: Zur Behandlung der Coxa vara, München. med. Wchnschr. **70**:1247 (Oct. 5) 1923.

45. Schwarz, Erwin: Ueber die Coxa vara congenita, Beitr. z. klin. Chir. **87**:685-708, 1913; Zur Frage der spontanen Epiphysenlösung (intracapsulären Schenkelhalsfraktur?) im Kindesalter, Beitr. z. klin. Chir. **87**:709-728, 1913.

The threefold displacement of the neck of the femur explains the deformity seen clinically. The lowering of the head of the femur produces limitation or absence of abduction. Limitation is not always due to a bony block, however; it is sometimes due to muscle spasm. As the head lowers, the limb attempts a compensatory abduction to overcome the effects of the displacement; in the more advanced cases, the limitation of abduction is due to the neck of the femur coming in contact with the upper rim of the acetabulum, the head tending to leave the acetabulum at its lower part. The anterior curvature of the neck causes external rotation of the leg which the patient instinctively combats with internal rotation until the latter is lost. In advanced cases the physiologic limit of internal rotation is reached before the external twist is compensated, and the limb seems turned out while the head is really rotated inward as far as possible. This rotation is brought about partly by posture and partly by the muscle pull of the external rotators, which are more powerful than the internal ones. The third component of the triple deformity is the twisting of the neck posteriorly on its longitudinal axis. This increases the range of extension.

A patient recently seen, who suffered from adolescent coxa vara associated with Fröhlich's syndrome, said he generally slept on his stomach and in that position he could raise the affected leg higher than the other. This increase in the range of extension can be demonstrated in two ways. One method is by Thomas' test. The patient lies supine on a rigid table, the sound thigh with the knee flexed is bent up until it comes in contact with the abdomen so that the lumbar vertebrae lie in contact with the table. The affected leg is then extended, the posterior surface of the knee easily coming in contact with the table. If the patient's buttocks are brought to the end of the table, his affected leg can be extended beyond 180 degrees without producing lumbar lordosis. The other method is to turn the patient on his stomach and fix his pelvis, when it will be found that the affected leg with the knee straight can be raised to a higher level than the sound leg without producing lumbar lordosis. This increase in the range of extension depends on the relaxation of the iliofemoral ligament and the assumption of control by the gluteus maximus muscle. On the extent of this relaxation depends the presence of Trendelenburg's phenomenon.

There is, therefore, an abduction deformity with eversion of the limb and an increase in the range of extension at the hip. If the patient is asked to flex the affected leg or if it is flexed passively, it will move upward parallel to the median plane until the foot reaches the level of the sound knee. If flexion is continued, the thigh will rotate outward at the hip so that the foot will pass quickly across the sound knee, assuming in bilateral cases the attitude of the tailor on his bench.[46]

46. Ogston, Alex: Coxa Vara, Practitioner **56**:347-359, 1896.

As the deformity progresses there is both real and apparent shortening. The real shortening is slight, an average of about 1.25 cm., but the apparent shortening is as a rule quite marked, owing to tilting of the pelvis from the patient's attempt to overcome the adduction deformity by bringing the affected leg into line with the sound one. In bilateral cases with a marked adduction deformity, the legs may be crossed, making locomotion extremely difficult. There are associated deformities in other parts of the body, such as muscle atrophy, compensatory scoliosis, flatfoot and knock-knee, and when adult life is attained secondary arthritic changes develop in the hip joint.

Congenital Type.—The symptoms may appear at any time up to the end of the fourth year of life, depending on the degree of hypoplasia. In many cases the child may limp as soon as he begins to walk, or he may walk with a distinct waddle. In other cases, there may be an apparent hypoplasia of the head and neck of the femur in the early years, and later a head and neck slowly appear, although they never attain complete development.

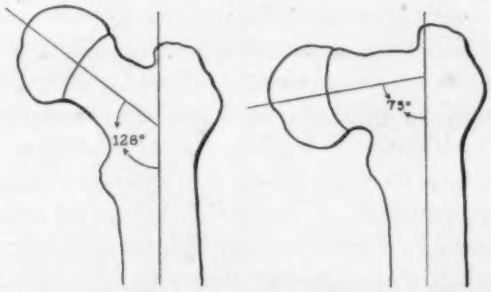

Fig. 10.—Diaphyseal angle in a normal femur and in one exhibiting a moderate degree of coxa vara.

As the deformity is gradual, there is no period of immobility which is so frequent an occurrence in the adolescent type. There is limitation of abduction and flexional deformity of the hip. The limb usually lies everted, but it may have the normal amount of rotation or even be inverted. The flexional deformity causes lordosis when the erect posture is assumed, and hence complete extension is impossible. In the bilateral cases, the gait is cross-legged, the trochanter is prominent, and lordosis is marked. There is both real and apparent shortening, and Trendelenburg's phenomenon is usually present. The disease is progressive, continuing until adult life, when in many cases the shortening is very marked.

MEASUREMENT OF ANGLES

Besides Bryant's triangle and Nelaton's line, which are familiar to all, several angles are used in the investigation of coxa vara. The three

that seem to be of the most value are: (1) the diaphyseal angle; (2) the direction angle, or angle of Alsberg, and (3) the angle of declination (Figs. 10, 11 and 12).

Diaphyseal Angle.—This is the angle between the neck of the femur and the shaft, and varies considerably with age and race. In man as well as in the lower animals there is a gradual decrease in this angle during growth and development. The average angle in the normal adult is 128 degrees; in the new-born it may reach as high as 143 degrees; in old persons it tends to decrease, and in the female it is always slightly

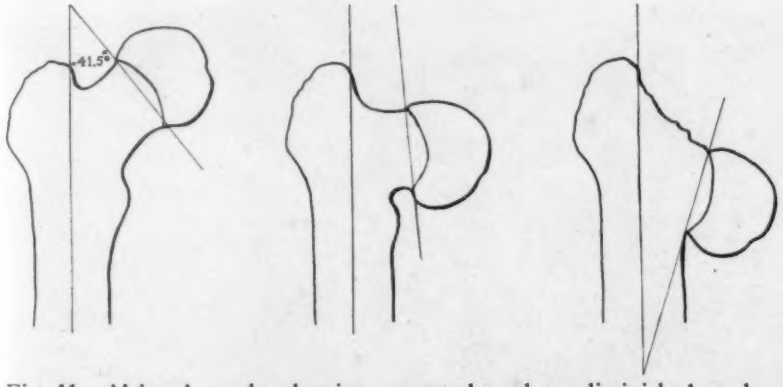

Fig. 11.—Alsberg's angle, showing a normal angle, a diminished angle and a negative angle.

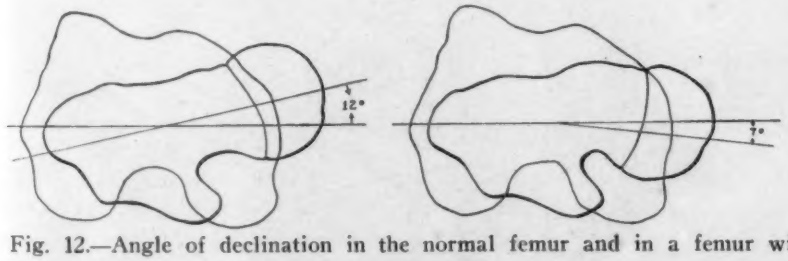

Fig. 12.—Angle of declination in the normal femur and in a femur with retroversion.

smaller than in the male. In coxa vara this angle may become a right angle or even less.

Direction Angle.—If frontal section of the head and neck of the femur is studied, the ends of the cartilaginous surface of the head will be found to be equidistant from the bony acetabular margin in the frontal plane; on joining those two cartilaginous points with a line and prolonging it until it intersects the femoral axis, the direction angle is obtained, which is on the average 41.5 degrees. The smaller the angle, the greater will be the varus position of the neck. In advanced cases

of congenital coxa vara, the angle may be a negative quantity, that is, it may appear on the opposite side of the neck. Helbing [25] has recently described a slight modification of this angle, using the prolongation of the epiphyseal line and the line of the axis of the femur. This slight modification gives an average angle of 57 degrees, and is subject to the same variation in coxa vara as Alsberg's angle.

Angle of Declination.—If the femur is observed from above, the head and neck are normally directed slightly forward; the angle formed

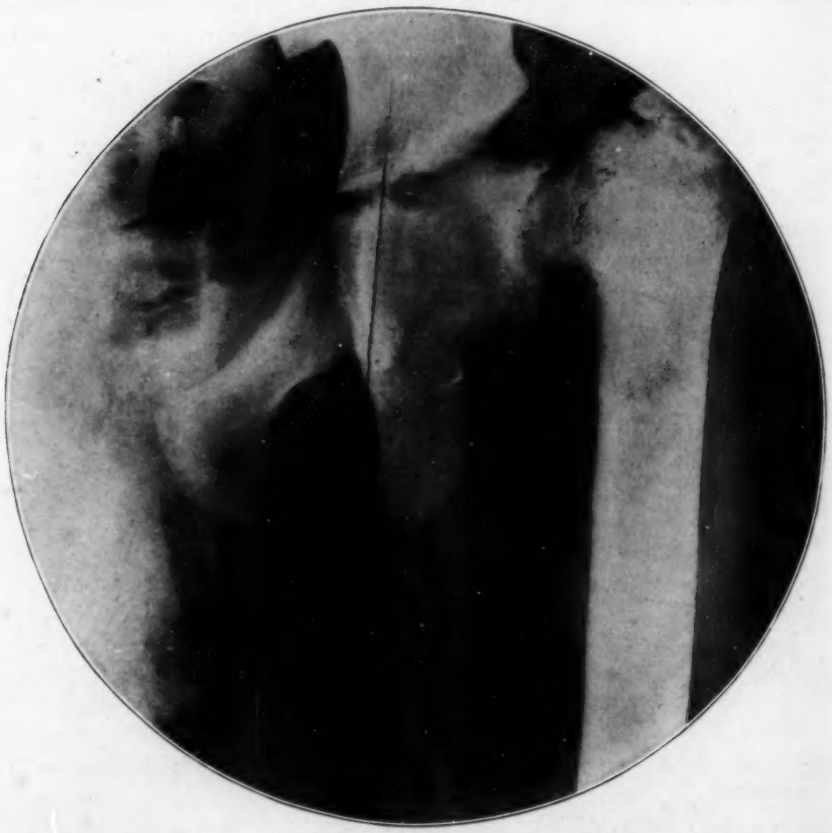

Fig. 13 (Case 1).—Appearance of upper end of femur ten years before operation.

by the long axis of the neck and the diaphyseal axis in a condylar plane is known as the angle of declination and is on the average 12 degrees. In coxa vara there is a backward displacement of the head with an anterior bowing of the neck, and hence this angle is diminished.

The acetabulum is subject to slight variations in the plane in which it lies, and consequently has a bearing on the movements of the hip joint. With a vertically directed acetabulum, the deformity is not so marked as in a more horizontally directed one.

EPIPHYSEAL SEPARATION

Epiphyseal separation is a condition distinct from coxa vara. Poland, in 1898, compiled thirty-three cases, but recently coxa vara has been mixed with slipped epiphyses in the literature, so that it is impossible to estimate its frequency, many cases of both adolescent and congenital coxa vara having been diagnosed as epiphyseal separation. This accident is, however, comparatively rare.

Experimental evidence goes to show that the position of abduction and extension is the most vulnerable one and most likely to produce

Fig. 14 (Case 1).—Appearance of upper end of femur immediately before operation.

detachment of the epiphysis; an exact reconstruction at the time of injury is difficult. The diaphyseal side of the epiphysis is the site of the separation, and the most common age of patients is between 14 and 18 years. The slipped epiphysis in a normal femur must of necessity be the result of a violent trauma. It is accompanied by an immediate functional impotence and has all the signs and symptoms of fracture of the neck of the femur.

ROENTGEN-RAY APPEARANCES

Adolescent Type.—A slight displacement at, or near, the epiphyseal line is sometimes rather difficult to detect. The line described by

Shenton [47] is very helpful in this connection. In the normal case it is an unbroken arch formed by the top of the obturator foramen and the inner margin of the femoral neck. The line is constant no matter what the position of the leg, whether it be adduction, abduction, internal or external rotation. Roentgenograms will not distort it.

However, many lesions of the hip, including coxa vara, will disturb this line. Figure 16 shows the difference between this line in the normal state and in coxa vara. In the latter there is a displacement at the epiphysis or close to it, and the epiphysis in the earlier phases of the disease is somewhat broadened. The neck is convex superiorly and anteriorly, and the head is often semilunar in shape. There is a diminution both of the diaphyseal and Alsberg's angle.

Congenital Type.—The roentgenographic appearances of the congenital type of coxa vara vary from complete absence to complete development of the head and neck with or without a fissure. The missing upper femoral end may ossify to some extent with growth. The fissure in the neck appears as a vertical light area in the roentgenogram or as an inverted Y, or more rarely still the neck may appear to be divided into several segments. The diaphyseal angle may be 90 degrees or less. There may be other associated changes, such as slight asymmetry of the pelvis with slight decrease in the dimensions of that side, and the roof of the acetabulum may be more steep. The femur is often more slender; the neck is shorter and convex upward.

PROGNOSIS

In congenital coxa vara, the progress of the disease is steady and uninterrupted from early childhood until adult life, when the neck disappears and the head becomes attached to the lesser trochanter. The resultant deformity is thus extreme and accompanied by marked shortening. The adolescent type runs a much shorter course, which is usually about three years, and consequently the ultimate deformity is much less. The condition then becomes stationary, but secondary arthritic changes develop later in life.

Preventive medicine in the future will probably play a considerable rôle in reducing the incidence of the adolescent type of coxa vara. As stated before, much evidence is being brought forward to show that the ductless glands in general and the pituitary gland in particular form the background for this disease. It is important to recognize the pituitary type of person, which is the one prone to this disease; treatment can then be instituted to supply the deficiency before any deformities appear,

47. Shenton, E. W. H.: Disease in Bone and Its Detection by the X-Rays, London, Macmillan Company, 1911.

as in rickets. Minor accidents in persons of this type should receive careful consideration, as the epiphyses are wide and succulent, and any minor trauma is likely to cause a gradual displacement in those situations.

During the three years that the disease is active, the epiphysis is wide and soft, and if weight is borne on the limb, the deformity is certain to progress.

Fig. 15 (Case 1).—Appearance of upper end of femur immediately after operation.

TREATMENT OF THE ADOLESCENT TYPE

In treatment of the adolescent type, one of three types of operative procedure may be employed: manipulation, double wedge osteotomy of the neck, or transtrochanteric osteotomy.

Manipulation.—Manipulation is of special use when slipping has taken place comparatively rapidly. The disease itself may have been in

evidence some time before a slight trauma which precipitates the displacement. Manipulative treatment may be carried out as long as six months after the displacement, even if there is pain and the patient is in one of the acute phases of the disease, for after the manipulation and fixation, all pain disappears.

The hip is practically immobile from muscle spasm, but under anesthesia there may be an almost complete range of passive motion. Manipulation is carried out with the patient under anesthesia, the limb being extended and brought into full physiologic abduction and slight internal rotation; a soft crepitus is usually felt as the surfaces fall into apposition. In this position a plaster-of-Paris cast is applied from the toes to the costal margin on the affected side, and to just above the knee on the sound side. This cast is kept on for three months when the patient is fitted with a walking caliper to be worn for six months, and then gradually discarded. By this time firm bony union has usually taken place at the site of the displacement.

Whitman [48] was the first to use manipulation for the reduction of the deformity of coxa vara. He pointed out that the range of normal abduction of the thigh is dependent on the upward projection of the neck, and that the extreme limit of abduction is reached when the neck and great trochanter come in contact with the rim of the acetabulum. Forcible abduction is therefore indicated as a means of replacing the depressed head of the femur. The rim of the acetabulum is used as a fulcrum, the shaft of the femur acting as a lever, and the capsular ligament as the point of fixation for the head. When full abduction with slight internal rotation is attained, the deformity has been reduced, and if the hip is fixed in that position, repair will take place.

Double Wedge Osteotomy.—Wedge osteotomy of the neck of the femur was first described and carried out by Kraske [49] in 1896, and has very recently been revived by Wilson.[50] This appears to be scientifically a better operation than subtrochanteric osteotomy, as it attacks the site of the deformity directly.

The chief objection to it is that the operation is performed through an area of bone with a scanty blood supply. This type of operation is especially indicated when there has been a slow and progressive slipping and the neck shows a distinct convexity upward and anteriorly. A

48. Whitman, Royal: A New Method of Treatment of Fracture of the Neck of the Femur, Together with Remarks on Coxa Vara, Ann. Surg. **36**:746-749, 1902.

49. Kraske, P.: Ueber die operativen Behandlung der statischen Schenkelhalsverbiegung, Zentralbl. f. Chir. **23**:121, 1896.

50. Wilson, P. D.: Displacement of Upper Epiphysis of Femur, Treated by Open Reduction, J. A. M. A. **83**:1749-1756 (Nov. 29) 1924.

Smith-Petersen incision gives the most satisfactory approach, and the removal of a double wedge of bone with its base upward and anterior is necessary. The limb is then put up in full abduction and slight internal rotation, and the remainder of the treatment is the same as that following manipulation. The healing of the bone following the wedge osteotomy leads to destruction of the epiphysis, firm bony union, and cure of the disease.

Transtrochanteric Osteotomy.—This operation, first carried out by Keetley, is still frequently performed. It is best performed through the area of bone between the two trochanters. If a small wedge of bone

Fig. 16 (Case 2).—Appearance of upper end of femur, Jan. 24, 1924; Shenton's line is noticeable.

is removed from that area the deformity can be easily and entirely corrected. The disadvantages are that it does not attack the site of the disease, and it is more than probable that the disease will complete its course and another osteotomy be required at a later date.

The extensive resections of the head and neck performed by Kocher and others about thirty years ago are not performed now. They were done in ignorance of the true nature of the disease, for the relief of pain and stiffness, and the shortening and resulting disability must have been considerable.

When deformities have resulted, the two latter types of osteotomy both yield excellent results. Occasionally a bilateral case is encountered in adult life with secondary arthritis, in which case excision of the head of the femur on one or both sides with wide abduction gives excellent results.

Other operations have from time to time been described, such as transplantation of the great trochanter with the attached gluteus medius and minimus muscles lower down on the shaft of the femur. Bone grafts have also been used to fix the head and neck. These are said to produce good results but are not in general use. Extension itself is of little value and never fully corrects the deformity.

TREATMENT OF CONGENITAL TYPE

Prophylaxis is of no avail in the congenital type of coxa vara, and the course of the disease cannot be divided into stages, as it is merely one of slow, steady progression. Operations on the neck are as a rule disastrous on account of the very poor blood supply to this region. If an osteotomy is performed, union is improbable. Subtrochanteric osteotomy does not attack the site of the disease, will be of temporary benefit only, and will add complications to any future operation. There are two operations of choice for this type: a plastic operation on the head and neck of the femur by the method of Brackett,[51] and the bifurcating operation of Lorenz. In the plastic operation, the neck of the femur is approached by the usual Smith-Petersen incision. The fissure in the neck is the site used for the separation of the head bearing portion from the remainder of the neck. This fissure is avascular and consists of noncalcified osteoid tissue; consequently the division is very simple. The portion of the neck remaining which is attached to the femur is removed. The lateral aspect of the head is freely curetted; the great trochanter with its attached muscles is transferred farther down on the diaphysis, and the upper end of the shaft of the femur is inserted into the lateral aspect of the head. The results of this operation are very satisfactory, and probably most satisfactory when performed during the period of adolescence.

The Lorenz bifurcating operation was originally performed for irreducible or late congenital dislocations of the hip, but has recently been performed for congenital coxa vara. First, an osteotomy is performed at the level of the acetabulum; then the upper end of the distal fragment is placed in the acetabulum, and union is sought for between the distal and proximal fragments, the latter consisting of head, neck and tro-

51. Brackett, E. G., and New, M. S.: Treatment of Old Ununited Fracture of the Neck of the Femur by Transplantation of the Head of the Femur to the Trochanter, Boston M. & S. J. **177**:351-353 (Sept. 13) 1917.

Fig. 17 (Case 2).—Appearance of upper end of femur one year after the patient came to the clinic.

Fig. 18 (Case 2).—Appearance of upper end of femur six weeks after operation.

chanters. The placing of the shaft in the acetabulum is the important part of the operation. The osteotomy is an oblique frontal one, performed at the middle point of the acetabulum, as in this plane it gives contact with the operative surface and insures bony union. A new joint is thus obtained. The limb is abducted from 45 to 60 degrees, depending on the amount of shortening which is produced, although apparently the limb is lengthened. The adductors are not tenotomized as they serve to keep the distal fragment in the acetabulum. The postoperative treatment consists in fixation in a case for three months, after which the patient is allowed to walk.

SUMMARY

The coxa vara of unknown etiology may be divided into two groups, congenital and adolescent. The congenital type, which is probably due to some embryonic vascular disturbance in the neck of the femur, is intimately associated with varying degrees of hypoplasia of the upper end of the femur. The mildest degree is by far the most common, and comes on any time up to the age of 4 years, then steadily progresses until adult life is reached. Roentgenograms of this type are characteristic, often being associated with a fissure in the middle of the neck of the femur. The adolescent type occurs generally in the obese or pituitary type of person. The incidence is most marked at the fourteenth year, when the adiposity is greatest. Adiposity and incidence diminish at the same rate until the nineteenth year when the disease has run its course and the patients are usually no longer adipose. There is considerable evidence that the pituitary gland plays an important part in this disease, and that trauma plays a minor part.

REPORT OF CASES

CASE 1.—A man, aged 21, came to the Mayo Clinic, Oct. 3, 1924, complaining of a limp and difficulty in walking. Nothing abnormal had been noticed at birth, but at about the age of 5 or 6 a limp had slowly manifested itself in the left leg, without apparent cause and without pain or discomfort. The leg had gradually become shorter, and during the last five years had been causing pain after excessive use. Previous treatment had consisted of rest and traction for a short period, then osteopathy, and later still the use of crutches from the tenth to the eighteenth year.

The patient was 5 feet 6 inches (153.6 cm.) in height, and weighed 110 pounds (49.9 kg.). The pulse and temperature were normal. The left leg was 5 cm. shorter than the right, with atrophy of both thigh and calf and a slight compsensatory scoliosis. Trendelenburg's sign was positive and the great trochanter was above Nelaton's line. There was marked limitation of abduction with increase in the range of adduction. Both internal and external rotation was limited and painful at the extreme limits of motion. The urine was normal; hemoglobin was 75 per cent.; the erythrocytes numbered 4,100,000, and the leukocytes 9,800, and the Wassermann reaction was negative.

A diagnosis of coxa vara of the congenital type was made; it appeared to be still slowly progressing. The neck of the femur was approached by a Smith-Petersen incision, and separation of the two fragments was easily carried out at the fissure in the neck, as it was found to be filled with fibrous tissue. The outer portion of the great trochanter with the attached muscles was then separated upward, and the upper portion of the diaphysis freshened as well as the outer aspect of the head. These two raw surfaces were brought together with the leg in wide abduction, the adductors having been tenotomized, and the great trochanter was fixed at a lower level on the shaft of the femur. The incision was closed and a cast applied from the ribs to the toes on the affected side, and to just above the knee on the unaffected side.

The patient was recumbent for two months, then bore weight with the cast for two more months, when he was dismissed from observation; he was much

Fig. 19 (Case 3).—Fröhlich's syndrome associated with marked coxa vara.

improved with only 2.5 cm. of shortening, and was able to walk without a cane (Figs. 13, 14 and 15).

Case 2.—A boy, aged 15, came to the Mayo Clinic, Jan. 24, 1924, complaining of pain in the left hip. About two months before, he awoke one morning with pain in the right hip, in spite of which he continued to get about. Three days later he wrenched the same hip and two days after this he had to go to bed on account of pain. He was confined to bed for four days, during which time he was seen by his local physician and a roentgenogram was taken, but no definite diagnosis was made. The pain and the limp continued much the same.

Examination revealed a healthy, fleshy boy, 5 feet 5.25 inches (165.7 cm.) in height, and weighing 154 pounds (69.9 kg.). He walked with a slight limp in

the right leg. There was a shortening of between 0.5 and 1.25 cm., with slight limitation of all movements of the hip, but more especially internal rotation and abduction. The urine was normal; hemoglobin was 75 per cent.; the erythrocytes numbered 4,400,000, and the leukocytes 7,000. A roentgenogram showed slight epiphyseal displacement, and a diagnosis of adolescent coxa vara was made.

The treatment advised at this time was a reduction diet with a high percentage of vitamins, restriction of activities, and rest for two hours each day. The patient was instructed to return to the clinic at once if any signs of an acute phase appeared. He returned November 28. His general health was

Fig. 20 (Case 4).—Hypoplasia of the head of the femur.

excellent, and he had lost 20 pounds (9 kg.), but the limp was more marked and the shortening was now 2.5 cm. On account of the steady progress of the disease, in spite of limited rest, diet, and so forth, an operation of the Kraske type on the neck of the femur was advised. Jan. 24, 1925, a double wedge osteotomy was performed through a Smith-Petersen incision. At the operation, the typical anterior and upward bending of the neck necessitated a complete osteotomy of the neck, a wedge being removed anteriorly and superiorly. Accurate apposition was obtained. The incision was closed and a cast applied from the rib margin to the toes on the affected side and to just above the

knee on the other side (Figs. 16, 17 and 18). Convalescence was uninterrupted and the result was excellent.

CASE 3.—A boy, aged 14, was brought to the clinic, May 9, 1924, because of obesity and a limp on the left side. He had been a full term child, but had had an instrumental delivery. At birth he had weighed 8.5 pounds (3.8 kg.); he had been breast-fed for twelve months, and had not walked until between 18 months and 2 years of age. His previous health had been good except that he

Fig. 21 (Case 5).—Congenital coxa vara with fissure of the neck.

had always been unusually fat, and during the last three years had gained 30 pounds (13.6 kg.) a year. Although he has always had a good appetite, he did not eat more than the average person. About two years before examination, pain and a limp had gradually developed in the left leg. These had increased in severity until the patient was brought to the clinic. His previous treatment,

which consisted of the administration of pituitary gland by mouth, had not been beneficial.

At examination the patient was very obese. His weight was 185 pounds (83.9 kg.), and his height 5 feet 6 inches (153.6 cm.). The boy was eunuchoid in type; he had no pubic hair; his genitalia were small, and the right testis was undescended. His left leg was 1.88 cm. shorter than the right, and when he stood the left heel was off the floor. The left leg was in external rotation, and there was limitation of both abduction and internal rotation with increase in the range of extension. The urine was normal; hemoglobin was 70 per cent.; the erythrocytes numbered 4,100,000, and the leukocytes 7,400. The differential count was lymphocytes 32 per cent., large mononuclears 2 per cent., transitional cells 3 per cent., neutrophils 61 per cent., eosinophils 1.5 per cent., and basophils 0.5 per cent. The Wassermann reaction was negative. The basal metabolic rate taken on two occasions was +8 and −5, respectively. Ophthalmoscopic examination showed nothing abnormal in the fundus, and the visual fields were normal. The vision in each eye was 6/6. Roentgen-ray examination showed the sella turcica to be normal, and the left hip to have a marked coxa vara of the epiphyseal type (Fig. 19).

A diagnosis of Fröhlich's syndrome with coxa vara of the epiphyseal type was made. The treatment advised was a diet to supply vitamins and reduce the weight, and the use of crutches. The patient was instructed to return in six or eight weeks for a double wedge operation on the neck of the femur.

Case 4.—A boy, aged 4 years, was brought for examination because of a limp. His mother had noticed that there had been something wrong with the hip since birth. As soon as he was able to walk, the limp had appeared. There was no pain associated with it, and he was otherwise quite well.

Examination revealed that the patient was well developed and well nourished. The pelvis was lower on the right than on the left, producing a compensatory lumbar scoliosis. The right leg was 7.5 cm. shorter than the left, and the great trochanter was above Nelaton's line. Trendelenburg's sign was positive and there was marked lumbar lordosis (Fig. 20). A diagnosis was made of coxa vara of the congenital type belonging to Group 3 of our classification.

Case 5.—A boy, aged 7 years, was brought to the Mayo Clinic, May 11, 1924, because of shortening and a limp in the right leg. His mother said that delivery had been normal and that he had been a full term child. He had begun to walk at the age of 18 months, when it was noticed that he waddled from side to side. This gait continued until the age of 3 when it changed to a limp, and it was noticed that the right leg was shorter than the left. At this time, the local physician was consulted; roentgenograms were taken and the condition diagnosed as hip disease. A tonsillectomy was performed, and a spica cast applied for one year. Following this, serum treatment was given for a year.

Examination showed that the patient was fairly well developed except for his right leg. He had a marked limp and walked with the aid of crutches. The right leg was 3.75 cm. shorter than the left. The right side of the pelvis was raised, producing a compensatory scoliosis. The right great trochanter was above Nelaton's line and Trendelenburg's sign was positive. Motion in the hip joint was good, except for limitation of abduction and internal rotation. His height was 3 feet 9 inches (93.2 cm.) and his weight 46 pounds (20.8 kg.). A roentgenogram showed congenital coxa vara with fissure of the neck. A diagnosis of congenital coxa vara was made. The parents refused operative treatment (Fig. 21).

GAUCHER'S DISEASE

WITH REPORT OF A CASE SHOWING BONE DISINTEGRATION AND JOINT INVOLVEMENT *

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Although Gaucher's splenomegaly is a disease with striking clinical characteristics almost as unique and unmistakable as the appearance of the big cells that cause the enlargement of the spleen, the diagnosis has very rarely been made except by microscopic examination. Apparently, this has been so because the comparatively few cases reported and the absence from the literature of any pictures illustrating the skin and eye signs have made this disease relatively unfamiliar to clinicians, although it is well known to pathologists.

The only form of treatment which has found general favor has been splenectomy. Apparently this has been done because the spleen was obviously the chief organ affected and at least some relief from symptoms caused by its bulk might be expected from its removal. For many years it has been known that the liver, bone marrow and lymph glands also contain the same large, mysterious cells that are found in the spleen, so that if these cells have anything to do with the progress of the disease, it is at least open to question whether splenectomy has any real curative effect. Unfortunately there exists very little published data as to late results of splenectomy, and as the disease is usually of long duration this information is necessary in order to judge of its therapeutic value.

The present article has two objects in view: to present the clinical features of Gaucher's disease with illustrations in order to make the disease more familiar and more often recognized clinically, and to attempt to evaluate the results of splenectomy as a therapeutic measure.

In 1882 Phillipe Charles Ernest Gaucher in his doctoral thesis at Paris described a new type of splenic tumor, which he called "d'epithelioma primitif de la rate; hypertrophie idiopathique de la rate sans leucemie." He summarized the disease as follows:

> There is a particular type of primary and idiopathic hypertrophy of the spleen to which I propose to give the name of primary epithelioma of the spleen because of its histological characteristics. The clinical aspects of this disease are:
>
> A marked splenic hypertrophy, progressive, of slow course, accompanied by quite severe spontaneous pains, by various signs of pressure, by hemorrhages (epistaxis, purpura and hemorrhages from the gums), occasionally by jaundice

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secondary to enlargement of the liver, without leukemia, without intermittent fever, without ascites, and ending in a marked cachexia.

Its anatomical characteristics are:

An extremely large (4.77 kg.), firm, hard spleen which shows a uniform enlargement and has a smooth surface and approximately normal shape and color.

Its histological characteristics are:

The complete substitution of the normal splenic tissue by large nucleated epithelial cells, polyhedral or irregularly rounded, which are enclosed within the normal trabeculae of the hyperplastic splenic pulp.

The next case of Gaucher's disease was reported thirteen years later, and it was eighteen years before Bovaird described the first case in this country. Including the original article, we have been able to find records of only forty-four [1] authentic cases, which are summarized here. We are indebted to Dr. Lawrence Smith for the information on the case reported from the Children's Hospital, Boston; to Dr. Gilbert Horrax for the case from the Peter Bent Brigham Hospital, Boston, and to Dr. Arnold Rich for the case from the Johns Hopkins Hospital (a full report of this case will soon appear in the literature). The other two cases are from the Presbyterian Hospital, New York.

Gaucher's splenomegaly occurs particularly in women and in children. It is characterized by progressive enlargement of the spleen, with bronzing of the exposed portions of the skin, and by anemia. A marked hemorrhagic tendency exists (epistaxis, bleeding from the gums, purpura, etc.). A yellow, wedge-shaped, conjunctival thickening, enlargement of the liver and leukopenia are usually present. Brothers and sisters are occasionally affected. Loss of weight may occur. There is no general adenopathy nor ascites. Pain in the extremities or over the spleen is occasionally present. Pathologic fractures have occurred. Death is usually due to an intercurrent infection—often tuberculosis. The pathologic picture is characterized by the presence of large round, oval or polygonal cells, which may have one or more nuclei, in the spleen, liver, lymph nodes and bone marrow. These cells have a pale acidophilic cytoplasm and do not contain lipoids. Their derivation is unknown but has been variously ascribed either to the reticular system of the spleen or to its endothelium.

ANALYSIS OF CASES REPORTED

The following is an analysis of the findings in the forty-nine cases reported in this article:

1. After this article had been submitted for publication the four cases published by E. Epstein (Virchows Arch. f. path. Anat. **253**:157, 1924) came to our attention. As the clinical data furnished was very meager it did not seem advisable to revise our figures to include these cases although they are undoubtedly authentic. They accentuate the tendency of these individuals to die at a relatively early age of intercurrent infections.

Age.—The first symptoms of the disease ordinarily make their appearance in childhood but the exact age is difficult to determine owing to the insidious onset. Twenty-eight of the forty-nine cases (58 per cent.) showed symptoms in the first decade (eighteen of the patients being under 5 years). The remainder of the cases are evenly distributed in the five periods up to 30 years. Sixteen cases were noted in patients more than 30—the oldest being 56 years.

Gaucher's splenomegaly is a chronic disease when observed in adults but may run a more acute course in children. There is one case with a two weeks' history.

Sex.—Females are more commonly affected than males; 67 per cent. of the cases occur in the former.

Spleen.—Marked splenic hypertrophy is found in all the cases. The spleen is frequently described as extending to the right of the midline and into the pelvis. The enlargement develops slowly and may grow so large as to give rise to a distinct protrusion of the left side of the abdomen. The surface is smooth and a notch is usually felt. In Gaucher's case the spleen weighed 4.77 kg.

Skin.—One of the most striking things in observing a patient is the discoloration of the skin of the exposed parts. Gaucher described the color as bister. It has been variously called by others "bronze," "tan," "brownish yellow" or "subicteric tint." This was noted in thirty-five cases (71 per cent.) and was absent in eight. This was not jaundice, as bile had not been found in the urine or blood serum. No report has been found of microscopic sections of the discolored areas of the skin.

Blood Picture.—The most striking feature of the blood count is the anemia and the consistent leukopenia. The average erythrocyte count is 3,000,000, and the average hemoglobin determination is 55 per cent. There is little change in size or shape of the cells. An erythrocyte count of 740,000 with a hemoglobin determination of 12 per cent. is reported. No abnormal cells are consistently present; no "Gaucher" cells have been found, and the proportion of leukocytes is not unusual. The average leukocyte count is 4,500 with a minimum of 500 cells and a maximum of 14,000 (this was noted in a child in whom the disease was of three weeks' duration). The bleeding and coagulation time were normal in the few cases in which these tests were done. The fragility test showed normal hemolysis.

Eyes.—There is a peculiar wedge-shaped thickening of the conjunctivae which was present in all the cases that Brill saw. This triangular area is slightly elevated and is yellow or brownish yellow. The base of it abuts against the cornea. It is said to occur first on the nasal side. These lesions resemble pingueculae, but the latter are more linear and

are apt to be pointed at the corneal end. The conjunctival thickening is not easily seen unless looked for with indirect illumination. It is necessary to stand at the side and look at the edge of the cornea while the patient is gazing straight ahead. It was noted in nine of the forty-nine cases and was said to be absent in thirteen. An icteric tint has been noted twice in the sclerae. Gaucher described in his case a yellow tint to the sclerae toward the inner angle of the eyes. The nature of this lesion is not known as no chemical or microscopic examination has ever been reported.

Liver.—The liver enlarges secondarily to the spleen and may be of considerable size. Its enlargement was noted in thirty-six cases (73 per cent.), and it could not be palpated in eleven cases. In twenty-seven cases the liver was between 3 cm. below the costal margin and the umbilicus.

Family History.—Other cases in the same family may have been present in twelve instances. Very few of these have been proved by pathologic examination. There is apparently no hereditary transmission, although the disease occurs in brothers and sisters.

Hemorrhages.—There is a definite hemorrhagic diathesis in the disease. Of the forty-nine cases, there were hemorrhages in thirty-two cases (65 per cent.) and none in five cases. No mention was made of it in twelve cases. Epistaxis was most common as it occurred twenty-one times. Bleeding from the gums, menorrhagia and purpura were reported, the frequency being in the order noted. The bleeding occurred from more than one site in fourteen cases.

Loss of Weight.—There is sometimes marked loss of weight, especially in the advanced cases. In eighteen cases in which loss of weight was mentioned, there were fifteen patients who showed emaciation.

Lymph Nodes.—Generalized lymphadenopathy is not a characteristic of the disease. Lymph glands were not palpated in twenty cases, and in nine a few small nodes were reported present in the axillary or inguinal regions.

Ascites.—Ascites is rare. Fluid in the abdominal cavity was noted in only three cases.

Pain.—Patients commonly complain of a dull pain over the spleen. This was present in fifteen cases and absent in eight. Pain in the extremities was noted in six cases, and in all of these the spleen was markedly enlarged.

Bone Lesions.—One of the patients from the Presbyterian Hospital first went to a doctor three and one-half years before because her right hip suddenly became stiff and painful and had limited motion. She

was told that she had rheumatism. The hip became progressively worse for two and one-half years. There was some shortening of the leg and the patient had considerable pain, especially at night. Roentgenograms were taken eighteen months before her admission to the hospital which showed some destruction of the head of the femur. She was put in a plaster cast at this time for a period of three weeks, and says that she was considerably worse afterward. The patient went to the New York Orthopedic Hospital before her admission to the Presbyterian Hospital, and the roentgenograms taken there showed destruction of the head of the femur with cavitation and erosion of the upper part of the acetabulum. It was thought to be a low grade staphylococcus infection. Roentgenograms were taken on her admission to the Presbyterian Hospital and the hip was thought to present the picture of an atypical neurotrophic joint. Roentgenograms of the remainder of the skeleton were negative.

The patient returned to the Orthopedic Hospital three months after the splenectomy, and the head and neck of the femur were resected by Dr. B. P. Farrell.

The sections of the bone showed the normal marrow to be almost entirely replaced by numerous large cells of the Gaucher type. Sections of the joint capsule showed thickening only.

In the review of the literature, two cases of pathologic fractures of the long bones were found, but no microscopic examination was reported in these cases.

Susceptibility to Disease.—These patients are apparently somewhat more susceptible to intercurrent infection than the average person. Four patients died of tuberculosis and four of other respiratory infections not associated with operation.

TREATMENT

Gaucher's disease is essentially one of long standing and marked chronicity. The usual medications for anemia (e. g., iron, arsenic and calcium) have all been used with little avail. Transfusions have been given without lasting benefit. Radiotherapy has resulted in transient decrease in the size of the spleen, but has not arrested the course of the disease.

Splenectomy was resorted to in twenty-nine cases. There were six operative fatalities, a mortality of 20 per cent. Shock and hemorrhage caused four deaths and peritonitis and tetanus each caused one. The patients that were not operated on died of various causes. Tuberculosis and pneumonia each caused four deaths. One patient died from cachexia, one from "hemorrhage from the mouth," and one from hemorrhagic pachymeningitis.

The reports are favorable from sixteen of the twenty-three patients surviving operation. They have gained in weight and strength and the hemorrhages have ceased. In two cases the liver decreased in size, and in four it increased. Carr and Moorhead's [2] patient lived twenty-one months after operation, and the patient continued to bleed from the gums. Clopton [1] writes that the liver has become larger in his patient, and his impression is that the patient is not very well five years postoperative. One of the patients from the Presbyterian Hospital, New York City, has been heard from five years and eight months after splenectomy. She writes that she is tired. Erdmann's [1] patient is well ten years after operation. Bruce [1] reports that his patient is living and in good health ten years after operation. Downes' [1] patient died of influenza six years after operation but considered herself well up to the time of her death. One of Mandlebaum's [3] patients is living three and one-half years following operation. Pool's [1] patient is well and has borne two children three years after her splenectomy. He stated that roentgenograms of the bones failed to show any thing abnormal and the blood examination was normal. There are four other patients reported living and well between one and two years postoperative.

TABLE 1.—*Results Following Splenectomy in Twenty-Nine Cases*

Operative Deaths	Unimproved or Worse	Symptom Free	Improved	Not Followed
6	5	7	9*	2

* Two of these patients have died: one after six years of influenza, and one eleven years after splenectomy.

It is very difficult to determine from such a small number of cases whether splenectomy has the effect of lengthening life. One method which may be suggestive is to select some definite age and to compare the average ages of those who lived past it with and without splenectomy.

If 30 years is selected, it is found that seven patients with Gaucher's disease lived past it without operation, dying at the ages of 47, 43, 41, 39, 34, 33 and 32 years, respectively, or at an average of 38.3 years. There were nine persons who lived to the age of 30 years and at some time after that had the spleen removed for Gaucher's disease. Seven were alive at the ages of 56, 48, 45, 44, 37.5, 33.5 and 32.5, and two were dead at 37 and 30 years. These patients lived an average age of

2. We are indebted to Drs. Moorhead, Clopton, Erdmann, Bruce, Downes and Pool for recent information regarding their patients subsequent to their published reports.

3. Dr. H. Lilienthal followed this case two years longer and wrote that the patient was in good general condition.

Fig. 1 (Case 2).—Characteristic pigmentation of the skin and conjunctival thickening.

40.5 years, and as seven of them were still alive when last heard from their average age at death will be higher. The number of cases is very small but the figures suggest that life is not at least shortened by splenectomy in Gaucher's disease and that it may be lengthened.

REPORT OF CASES

CASE 1.—R. W., aged 29, a well developed and nourished, unmarried Russian woman, a secretary, was admitted to Presbyterian Hospital, New York, Jan. 20, 1919, complaining of a gradual onset of abdominal discomfort for five weeks.

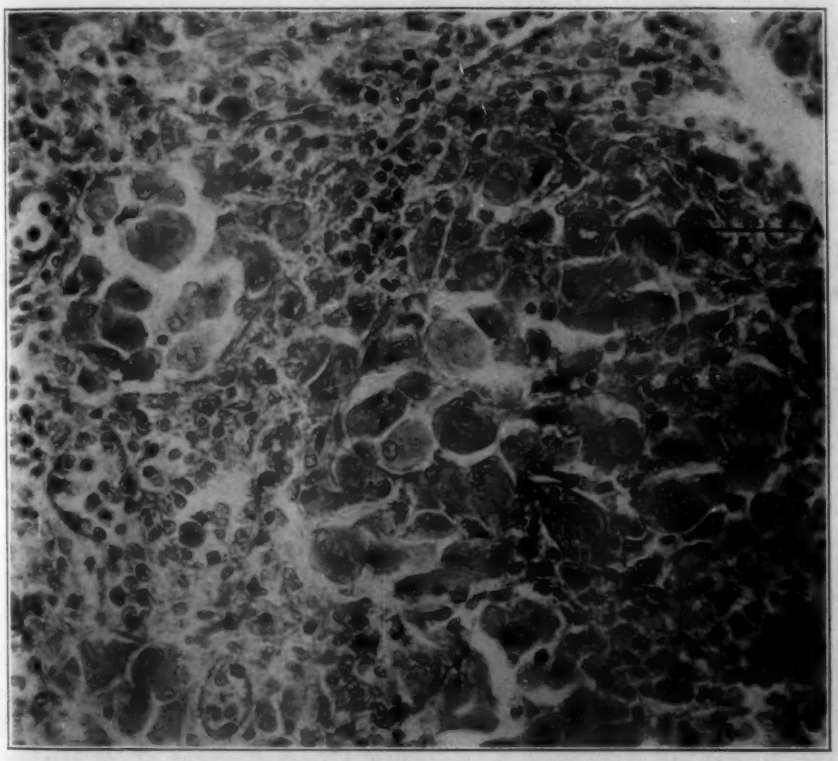

Fig. 2 (Case 1).—Characteristic large cells in the spleen; eccentrically placed nuclei and finely striated cytoplasm. Above and to the left is a dilated venous sinus filled with the cells, many of them lying apparenty unattached to the walls. *A*, an arteriole entirely unaffected by the process.

Her father, mother and a cousin had tuberculosis. She had always been fairly well and had had no acute infectious diseases. She had been chronically constipated and frequently had headaches. She had had a poor appetite for four months, and considerable belching of gas for five months. There had been a slight cough for ten years. The cardiorespiratory, gastro-intestinal and genito-urinary histories were otherwise negative. The catamenia were normal.

She had lost 11 pounds (5 kg.) in weight in nine months. She had had attacks of epistaxis frequently for the last twelve years. She stated that her

skin had been yellowish at times. An osteopath had given her abdominal massage for four months, and she said these treatments had helped her general health. For five weeks before admission she had had considerable discomfort after eating, which was relieved by soda and belching.

The patient did not appear acutely ill. Her face was brown. The pupils were equal and active and the conjunctivae were clear. The ears, nose, mouth and throat were negative. The lungs were clear. The heart was not enlarged and there were no murmurs. The abdomen showed a protrusion in the left upper quadrant. The spleen was markedly enlarged, and extended to the umbilicus and to the crest of the ileum. It was firm, nontender and had a sharp edge. The liver edge was palpable 2 cm. below the costal margin. There was no ascites. There were small palpable deep cervical nodes, but no others were felt.

The Wassermann reaction and blood culture were negative. The patient's blood was Group I (Jansky). The red blood cells totaled 4,288,000; the white blood cells, 5,000; the hemoglobin determination was 90 per cent. The polymorphonuclear leukocytes totaled 72 per cent.; the large lymphocytes, 16 per cent.; the small lymphocytes, 12 per cent., and the transitionals, 1 per cent. The red cells were normal in appearance. In the fragility test, hemolysis occurred between 0.2 and 0.35 per cent. Roentgen-ray examination of the chest was negative. A gastro-intestinal series showed apparent adhesions of the duodenum and suggestive pericolic adhesions at the hepatic flexure. The patient was thought to have early Banti's disease and splenectomy was advised.

Splenectomy was done by Dr. A. O. Whipple, Feb. 1, 1919, through a left rectus incision. The spleen was easily delivered, as there was little perisplenitis. The liver was not definitely enlarged but had a slightly granular surface. The gallbladder was bifid, but the biliary tract was otherwise negative. The spleen weighed 999 gm. and measured 21 by 11.5 by 6 cm. The contour was an enlarged replica of a normal spleen. The surface was smooth except for a few delicate fibrous adhesions at the upper pole. The capsule was less than half a millimeter thick; it was rather soft and, when cut into, the splenic substance bulged forward very slightly. It was brick red, speckled over with tiny short pearly gray lines which probably represented the trabeculae. The splenic corpuscles could not be made out. There were three dark red areas of fresh hemorrhage into the splenic substance, the largest of which was 2 cm. in diameter. The blood vessels at the hilum and within the splenic substance appeared thin walled and normal.

Microscopic examination of sections made from different parts of the spleen showed everywhere the same picture. The pulp was filled with large cuboidal cells varying roughly from 20 to 40 microns in diameter. Their nuclei varied from 1, which was usual, up to as many as 9. They were, as a rule, eccentrically placed and had a distinct nucleolus and nuclear markings. No mitoses could be found. The cytoplasm stained a rather faint red within eosin, was very finely granular, and showed fine anastomosing lines coursing through it in all directions. In some areas, these cells contained granules of iron containing blood pigment. They showed no vacuoles and contained nothing that would stain with scharlach r. These cells filled the pulp and distended the sinuses. In many places they seemed to lie among the red blood cells in the sinuses, but they were never found within the lumina of any of the splenic blood vessels, with which this spleen seemed to be very plentifully supplied.

In some parts of the spleen the pulp seemed to be almost entirely filled with these cells which were supported by a delicate connective tissue stroma. There were very few other pulp cells and no splenic corpuscles. In other sections

splenic corpuscles of small size could be found at rather wide intervals, and a scattering of pulp cells was seen among the larger cells.

Study of the gross spleen and sections from it suggested that the enlargement was due almost exclusively to the presence of the large cells in the pulp and its sinuses. Their nature was not determined. At least one could feel fairly confident that they did not come into actual contact with endothelial cells, which suggested that they were not derived from endothelium. They seemed to belong to the connective tissue elements, but nothing has been done to prove that they were reticulum cells.

The patient had an uneventful postoperative recovery and was discharged on the twentieth day postoperative.

Fig. 3 (Case 2).—Patient's face shortly after splenectomy, showing the conjunctival thickenings and the dark hue of the skin.

Two months after operation, she still had some gas and sour eructations. The red blood cells totaled 4,100,000; hemoglobin was 85 per cent., and white blood cells were 15,000.

Four months after operation, she continued to have some epigastric distress. A gastric test meal gave free hydrochloric acid 24, total acids 46. A guaiac test was negative.

Eight months after operation, she had gained 8 pounds (3.6 kg.). She still had some epigastric discomfort. There was a slight increase of pigmentation on the face. The patient showed a marked tendency to introspection.

Sixteen months after operation, she had gained 2 pounds (0.9 kg.). The skin was slightly more bronzed. She had some abdominal discomfort when nervous. The liver was not palpable.

Twenty-five months after operation, the skin was still pigmented, and there was some "pain" in the epigastrium.

Thirty-six months after operation, the condition was practically unchanged.

Sixty-eight months after operation, the patient, who had gone to California to live, wrote to a friend that she feels tired.

CASE 2.—M. W., an unmarried American woman, aged 33, a music teacher, was admitted to the Presbyterian Hospital, New York, July 20, 1924. She had been referred from the New York Orthopedic Hospital because of anemia and a large spleen. One brother and one sister who were examined had no pigmentation, enlarged spleen or conjunctival thickening. One brother was not examined.[4] The patient had no history of acute infectious diseases. Cardiorespiratory, gastro-intestinal and genito-urinary histories were negative except as given below. She had not lost weight. She had always been very athletic until inhibited by her hip. She had severe epistaxis every two to three months as a child until catamenia started. She had also had some epistaxis for the last eighteen months. She had been "yellowish" all her life and had noted that her "eyeballs" were yellowish for some years. Her gums had bled easily the last year. The last sixteen months the patient had had profuse and irregular periods. A year before admission, she had been told that she was anemic. Three and one-half years before admission, her right hip suddenly became stiff and painful and motion became limited. This continued and the leg began to shorten. Eighteen months before admission, the patient was put up in a plaster cast for eight weeks, but was worse after it. She went to the Orthopedic Hospital and roentgenograms taken there showed marked destruction of the head of the femur with cavitation of the neck and erosion of the upper part of the acetabulum. Tuberculosis was considered unlikely, and it was thought to be a low grade staphylococcus infection.

Physical examination showed the patient a well-developed, thin woman with "tanning" of the face and arms. The pupils were equal and active. The ears, nose, mouth and throat were negative. There was no enlargement of the cervical, axillary, epitrochlear or inguinal glands. The lungs were clear. The heart was not enlarged and there was a soft systolic murmur at the apex. The abdomen was rounded. The spleen was markedly enlarged, extending from the costal margin to 4 cm. below the umbilicus in the middle of the abdomen. The liver was palpable 1 cm. below the costal margin. The right hip was held flexed with moderate eversion, and the greater trochanter was flattened and was 3 cm. higher than on the left. The right leg was 3 cm. shorter than the left. There were no sensory changes. The examination was otherwise negative.

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4. After this article was accepted for publication, this brother was examined and found to have all the stigmas of Gaucher's disease, including epistaxis, bronzing, corneal signs, anemia and large spleen and liver. Roentgen-ray examination of the bones was negative. In addition he had a basal metabolism averaging plus 60, and he was emaciated. After a period of rest and a transfusion, a spleen weighing 2,667 gm. was removed which showed the characteristic large cells; these also were found in the lymph nodes at the hilum of the spleen. The patient did not rally after the operation and died three days later with shock, convulsions and bronchopneumonia. At necropsy the liver weighed 2,650 gm. and much of the liver substance seemed to be replaced by the large cells.

The red blood cells totaled 1,300,000; hemoglobin, 23 per cent. (Dare); white blood cells, 2,900. Polymorphonuclear leukocytes totaled 75 per cent.; lymphocytes, 22 per cent.; eosinophils, 1 per cent.; large mononuclears, 1 per cent.; and metamyelocytes, 1 per cent. The red cells showed central achromia with some polychromatophilia. The platelets appeared normal. The reticulated cells

Fig. 4 (Case 2).—Hip joint in April, 1923, three years after the hip trouble began, showing marked destruction of the acetabulum and of the head and neck of the femur.

totaled 1.2 per cent. The bleeding time was one minute and thirty seconds; coagulation time was four minutes. In the fragility test, hemolysis was from 0.38 to 0.46 per cent. The blood was Group I (Jansky). The Wassermann reaction was negative. Roentgen-ray examination of the chest was negative. The patient received three direct transfusions, totaling 2,500 c.c. She was transferred for operation to the surgical service at a time when her red count

was 4,100,000 and the hemoglobin determination was 70 per cent. Splenectomy was advised, as it was thought that the spleen was due to a secondary anemia. Diagnoses of amyloid spleen, pernicious anemia and hemolytic jaundice were thought improbable; the pigmentation was explained by sunburn, and Gaucher's disease was thought unlikely.

Fig. 5 (Case 2).—Hip joint, December, 1924, just before operation on the joint at the New York Orthopedic Hospital; it shows apparent progress in the destruction of the head and neck of the femur.

Splenectomy was done by Dr. A. O. Whipple, Aug. 26, 1924, through a 20 cm. left rectus incision. There were few adhesions to the diaphragm, and the vessels at the hilum were not brittle. Two small lymph nodes were noted at the hilum of the spleen.

The spleen weighed 1,017.5 gm. in the fresh state immediately following splenectomy. It measured 29 by 16 by 8.5 cm. The capsule was relatively

Fig. 6 (Case 2).—Spleen after fixation in formaldehyd, showing the hylic surface. It measured 29 by 16 by 8.5 cm. and weighed 1017.5 gm.

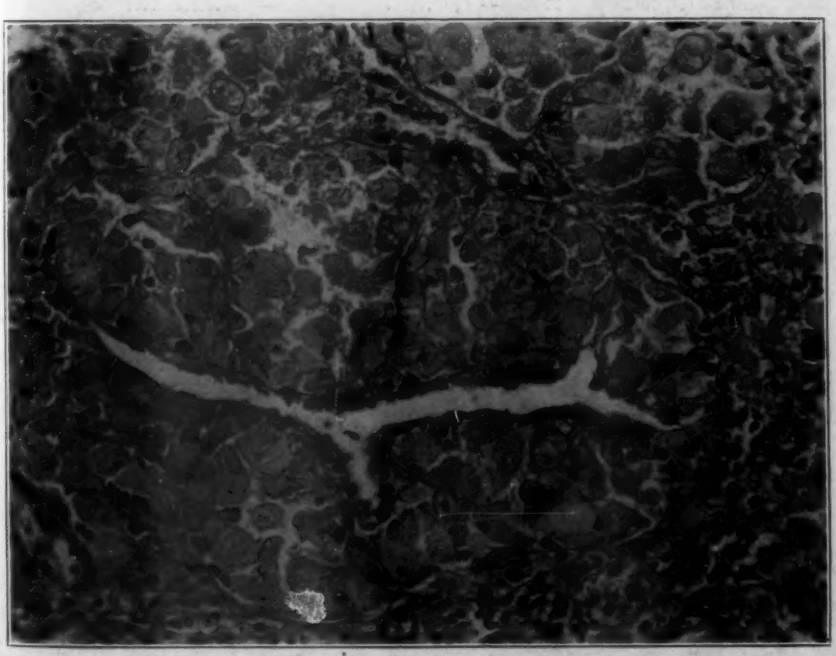

Fig. 7 (Case 2).—Pulp, showing large cells filling and dilating the splenic sinuses. The space passing across the center is a blood vessel which is surrounded by large cells but which has intact lining and walls.

TABLE 2.

Author	Age and Sex	Age at Reputed Onset	Family	Weight	Pain: Spleen	Pain: Bones	Hemorrhages	Discoloration of Skin	Eyes	Spleen	Liver
1. Gaucher, E.: Thèse de Paris, 1882.....	32 ♀	7	.....	Emaciated	..	+	Epistaxis ecchymoses	+	Yellow	++++	++
2. Collier: Tr. Path. Soc. London **46**: 148, 1895	6 ♀	2	Sister died with big spleen	.....	..	..	Epistaxis	..	..	++	–
3. Picou and Ramond: Bull. Soc. anat. de Paris **70**: 531, 1896; Arch. de méd. expér. et d'anat. path. **8**: 168, 1896	32 ♀	28	—	.....	+	..	Gums, menorrhagia	+	..	+++	–
4. Bovaird: Am. J. M. Sc. **120**: 377, 1900	13 ♀	3	Sister had bronze skin cachexia	.....	+	..	.....	+	..	++++	–
5. Brill, Mandlebaum and Libman: Proc. New York Path. Soc. **4**: 143, 1904; Am. J. M. Sc. **129**: 491, 1905	34 ♂	19	Sister	Loss	—	?	Epistaxis	+	+	++++	+
6. Schlagenhaufer: Verhandl. d. deutsch. path. Gesellsch. **10**: 77, 1907; Virchows Arch. f. path. Anat. **187**: 125, 1907	43 ♀	5	Sister had big spleen	.....	..	..	Epistaxis	+	Icteric	++++	++
7. Von Herczel: Wien. klin. Wchnschr. **20**: 123, 1907	37 ♀	31	.....	.....	+	..	Epistaxis, menorrhagia	..	..	+++	+
8. Marchand: München. med. Wchnschr. **54**: 1102, 1907	.. ♀	..	.....	.....	..	..	Tendency to hemorrhage	+	..	+++	+
9. Brill, Mandlebaum and Libman: Am. J. M. Sc. **137**: 849, 1909	39 ♀	21	Brother	Loss	..	+	Epistaxis	+	+	+++	++
10. DeJong, R. D., and Van Heukelom, J. S.: Beitr. z. path. Anat. u. z. allg. Path. **48**: 508, 1910	12½ ♀	7½	Brother and sister	.....	+	..	Epistaxis	+	—	+++	++
11. Mandlebaum, F. S.: J. Exper. Med. **16**: 797, 1912	4½ ♂	3½	Sister	.....	..	..	Epistaxis	+	—	+++	++
12. Wilson: Surg., Gynec. & Obst. **16**: 240, 1913	27 ♀	12	.....	.....	..	..	.....	..	..	++++	+++
13. Downes, W. A.: Med. Rec. **83**: 697, 1913	28 ♀	15	—	.....	+	+	.....	+	+	++++	++
14. Babes, Aurel and Babes: Compt. rend. Soc. de biol. **75**: 575, 1913	22 ♀	21	—	.....	+	..	.....	..	..	+++	–
15. Sapegno: Arch. per le sc. med. **37**: 323, 1913	47 ♂	..	.....	.....	..	..	.....	+	..	+++	..
16. Stevenson: Brit. M. J. **2**: 847, 1913....	22 ♀	? 13	.....	Emaciated	+	..	Epistaxis, menorrhagia	—	..	++++	+++
17. Erdmann, J. F., and Moorhead, J. J.: Am. J. M. Sc. **147**: 213, 1914	3¾ ♀	1	—	.....	..	..	.....	—	—	+++	++
18. Niemann: Jahrb. f. Kinderh. **79**: 1, 1914	17 mo. ♀	2 mo.	.....	Loss	..	..	.....	+	..	++	++
19. Hermann: Arch. Pediat. **31**: 340, 1914..	14 ♂	7	Sister	Loss	+	..	Gums, hemoptysis	+	+	++	+++
20. Bruce, H. A.: Tr. Am. Surg. A. **33**: 288, 1915	46 ♂	43	—	.....	+	Numb legs	Epistaxis	+	..	++++	–
21. Evans, F. A.: Proc. New York Path. Soc., June, 1916	4 11/12 ♂	2	—	—	..	..	.....	—	—	++++	++
22. Veeder and Clopton, M. B.: J. Missouri M. A. **14**: 49, 1917	4½ ♂	4	—	.....	..	..	Epistaxis, gums	+	+	++++	+++
23. Reuben, M. S.: New York M. J. **107**: 118, 1918	2 ♂	6 mo.	? Sister	.....	..	..	Epistaxis	+	—	++++	+++
24. Mandlebaum: Am. J. M. Sc. **157**: 366, 1919	41 ♀	6	—	—20 lbs. (9 kg.)	..	+	Purpuric spots	+	—	++++	+++
25. Mandlebaum: Am. J. M. Sc. **157**: 366, 1919	37 ♂	25	—	—	+	..	Epistaxis	+	+	++++	–
26. Carr and Moorhead, L. D.: J. A. M. A. **72**: 19, 1919	46 ♂	9	—	Emaciated	—	..	.....	+	..	++++	+++
27. Guyot: Ass. franç. de chir. Proc.-verb. **29**: 424, 1920	43 ♀	5	—	.....	+	..	Hemoptysis	+	..	++++	–
28. Barat: Folia haematol. **26**: 206, 1920..	33 ♂	18	—	.....	..	..	.....	..	..	++++	++
29. Kraus: Ztschr. f. ang. Anat. **7**: 186, 1920	17 ♀	..	.....	Thin	..	..	Epistaxis	+	..	+++	+++
30. Kraus: Ztschr. f. ang. Anat. **7**: 186, 1920	1 ♀	6 mo.	.....	.....	..	..	.....	+	..	+++	..

2. *Summary of Cases**

Nodes	Ascites	Blood: Red Blood Cells	Blood: Hemoglobin	Blood: White Blood Cells	Treatment	Postoperative Blood: Red Blood Cells	Postoperative Blood: Hemoglobin	Postoperative Blood: White Blood Cells	Remarks
—	—	2,281,000	..	3,027	Iron and arsenic	.....	..	.....	Died of pulmonary tuberculosis
—	—	Normal	..	No excess	.....	.....	..	.....	Died, "sickness"
—	—	Anemia	..	.....	Splenectomy (Bouilly)	3,500,000	50	.....	Postoperative weight, +12 pounds (5.4 kg.); 5 months postoperative, liver enlarged
Small right inguinal and axillary	..	2,800,000	60	4,000	Splenectomy (McCosh)	.....	..	.....	Died 3 hours postoperative
Small axillary	—	4,400,000	55	5,240	.....	.....	..	.....	Died of hemorrhagic pericarditis
Tuberculous glands of neck	..	4,700,000	65	1,300	.....	.....	..	.....	Died of tuberculosis
.....	..	4,200,000	92	7,000	Splenectomy (von Herczel)	4,600,000	90	8,000	Five months postoperative, liver same size
.....	..	Unchanged			.....	.....	..	.....	Twenty years' duration; no clinical history; died from exhaustion
Slight general	—	3,500,000	35	3,600	.....	.....	..	.....	Died from an accident
.....	..	.....	..	.....	Splenectomy (von Rossem)	.....	..	.....	Six months postoperative, patient well; liver larger
—	..	2,200,000	35	500	Splenectomy (Wiener)	.....	..	.....	Died 24 hours postoperative
.....	+	5,200,000	80	4,200	Splenectomy (W. J. Mayo)	.....	..	.....	Died 12 hours postoperative of shock and hemorrhage
—	—	3,800,000	49	900	Splenectomy (Downes)	Slight secondary anemia			Patient was well until 36 months postoperative; liver increased in size, to groin; postoperative gain in weight; died 6 years posoperative of influenza
—	..	4,800,000	Normal		Splenectomy (Leconte)				
..	.....	.....	..	.....	.....	.....	..	.....	Died of pulmonary tuberculosis
.....	..	1,500,000	83	4,568	Splenectomy (Stevenson)	4,400,000	83	11,200	
Small inguinal	—	6,200,000	85	7,000	Splenectomy (Erdmann) radiotherapy useless	.....	..	.....	Ten years postoperative, patient well, not robust; liver smaller
—	+	Normal			.....	.....	..	.....	Died
Small axillary and inguinal	..	3,800,000	64	2,800	Splenectomy (Roth), iron and arsenic, radiotherapy	3,300,000	50	15,000	Two months postoperative, very well; postoperative weight, +4 pounds (1.8 kg.)
.....	—	3,500,000	65	4,800	Splenectomy (Bruce)	4,700,000	65	9,400	One month postoperative, less pigment; 120 months postoperative, living and in good health
Palpable inguinal	—	.....	..	.....	.....	.....	..	.....	Died, grand mal, acute bronchitis, petechial hemorrhages in epicardium
.....	..	3,700,000	55	4,400	Splenectomy (Clopton)	4,800,000	90	20,000	Seventeen months postoperative, no hemorrhages; liver same size; 60 months postoperative, liver larger, not so well; postoperative gain in weight
.....	..	3,500,000	55	4,500	.....	.....	..	.....	Splenectomy advised; diagnosis by splenic puncture
—	..	3,200,000	50	2,000	Splenectomy (Lilienthal)	.....	..	.....	Postoperative weight, +13 pounds (5.9 kg.); blood cholesterol, 0.0875%; 1 month postoperative, patient well; 42 months postoperative, patient well
—	+	3,500,000	35	9,000	Splenectomy (Berg)	.....	..	.....	Died 17 days postoperative
—	..	2,240,000	35	3,200	Splenectomy (Percy)	4,900,000	90	9,000	Postoperative loss in weight; 21 months postoperative, some bleeding from gums, liver unchanged
Palpable inguinal	—	3,500,000	..	6,100	Splenectomy (Guyot)	6,500,000	..	14,000	Postoperative gain in weight; 12 months postoperative, patient well
.....	..	5,400,000	..	5,600	.....	.....	..	.....	Followed 9 years; died of tuberculosis and diabetes
.....	..	2,400,000	42	3,750	Splenectomy (Lieblein)	3,200,000	55	8,000	Twelve months postoperative, patient very well; liver smaller
.....	..	Nothing abnormal			.....	.....	..	.....	Died of pneumonia

TABLE 2.—*Summa*

Author	Age and Sex	Age at Reputed Onset	Family	Weight	Pain: Spleen	Pain: Bones	Hemorrhages	Discoloration of Skin	Eyes	Spleen	Liver
31. Rusca: Haematologica, Naples, **2**: 441, 1921	11 mo. ♂	8 mo.	—	Thin	+	..	—	+	—	++++	+++
32. Keismann: Med. Klin. **17**: 72, 1921.....	17 ♀	9	—	Loss	..	..	Petechiae on extremities	+	..	+++	++
33. Pool, E. H.: Ann. Surg. **74**: 635, 1921	26 ♀	25	—	—13 lbs. (5.9 kg.)	+	..	Epistaxis and ecchymoses after trauma	—	—	++++	–
34. Siegmund: Verhandl. d. deutsch. path. Gesellsch. **18**: 59, 1921	9 mo. ♀	1 wk.	? Sister	.....	..	..	.....	..	..	++	++
35. Foot and Ladd: Am. J. Dis. Child. **21**: 426, 1921	8 ♂	7	—	Loss	?	Legs	—	—	..	+++	–
36. Levy: New York M. J. **113**: 586, 1921..	30 ♀	26	—	.....	+	..	Epistaxis, gums	+	—	++++	+++
37. Lippmann: Med. Klin. **18**: 1607, 1922...	.. ♀	..	—	—	+	..	Epistaxis, gums, menorrhagia	+	+	++++	++
38. Harvier and Lebec: Bull. et mém. Soc. méd. d. hôp. de Paris **47**: 87, 1923	20 ♀	13	Sister	.....	+	—	Metrorrhagia	—	—	++++	–
39. Fahr and Stamm: Monatschr. f. Kinderh. **26**: 169, 1923	3 ♂	$2^{10}/_{12}$	—	.....	..	..	Epistaxis	+	..	++++	++
40. Zadek, I.: Med. Klin. **20**: 78, 1924.....	41 ♂	30	.....	—20 lbs. (9 kg.)	—	—	Gums, hematemesis, petechiae	+	Icteric	++++	++
41. Reber, M.: Jahrb. f. Kinderh. **105**: 277, 1924	5 mo. ♀	5 mo.	? Sister	.....	..	..	Hematemesis	..	..	++	++
42. Waugh and MacIntosh: Arch. Int. Med **33**: 599, 1924	5 ♀	3	—	—	—	—	—	+	—	++++	++
43. Reuben, M. S.: Arch. Pediat. **16**: 456, 1924	15 ♂	..	—	.....	..	..	Epistaxis	+	..	++++	+++
44. Schuster, N. H.: Lancet **2**: 170, 1924...	$11^{10}/_{12}$ ♀	$13^{1}/_{4}$	—	Loss	..	..	Petechiae	+	—	++++ (tender)	–
45. Case, Children's Hospital, Boston.....	$2^{7}/_{12}$ ♀	$1^{7}/_{12}$	—	—	—	—	—	+	..	++++	++
46. Case, Peter Bent Brigham Hospital, Boston	13 ♀	6	—	.....	..	..	—	—	..	++++	++
47. Case, Johns Hopkins Hospital, Baltimore	13 ♀	18 mo.	—	Loss	—	+	Epistaxis	+	—	++++	++
48. Case 1, this article.....	29 ♀	..	—	—11 lbs. (5 kg.)	—	—	Epistaxis	+	+	++++	++
49. Case 2, this article.....	33 ♀	32	—	—	—	Hip	Epistaxis, gums, menorrhagia	+	+	++++	+

* In this table, ♂ indicates male, ♀ female; + present, — absent. In regard to the liver and spleen, ++++ indic

smooth without wrinkles and was not thick. The contour was an enlarged replica of an average spleen. On section the cut surface was dark brick red, rather soft but not pultaceous, and of a uniform consistency. The pulp was everywhere speckled with very fine white threadlike lines, a millimeter or less in length, representing trabeculae. The splenic corpuscles could not be seen. The blood vessels at the hilum and within the body of the spleen had soft normal walls and showed nothing remarkable. At the hilum was a small lymph gland about 5 mm. in diameter.

Microscopic examination of sections made from different parts of the spleen showed the same picture. The pulp was filled with large cuboidal or roughly ovoid cells, varying from 20 to 45 microns in their various diameters. They had a relatively small, eccentrically placed nucleus averaging from 6 to 7 microns in diameter. The nucleus usually had a single nucleolus and well defined nuclear markings. Some of the large cells had more than one nucleus; as many as five could be counted in one cell. No mitoses could be found. The cytoplasm was very considerable in amount, was granular, took a brownish

Cases—Continued

Nodes	Ascites	Blood: Red Blood Cells	Blood: Hemoglobin	Blood: White Blood Cells	Treatment	Postoperative Blood: Red Blood Cells	Postoperative Blood: Hemoglobin	Postoperative Blood: White Blood Cells	Remarks
Small cervical and inguinal	..	3,160,000	40	10,000	.....	.....	..	.....	Died of suffocation
—	—	2,400,000	42	3,700	Splenectomy (Keismann)	.....	..	.....	Twelve months postoperative, patient doing well
.....	..	3,800,000	68	3,400	Splenectomy (Pool)	.....	..	.....	Thirty-six months postoperative, patient doing well; has had two children
.....	..	Anemia			.....	.....	..	.....	Died of pneumonia
—	—	5,800,000	90	6,000	Splenectomy (Ladd)	4,900,000	80	18,800	Postoperative weight, +6 pounds (2.7 kg.); 8 months postoperative, fairly well
—	—	3,200,000	..	6,400	Splenectomy (Reilly)	.....	..	.....	Died 9 days postoperative, ? tetanus; no necropsy
.....	..	4,500,000	95	3,200	.....	.....	..	.....	Diagnosis by splenic puncture; expectant treatment as no anemia
—	—	Absence of leukemia			Splenectomy (Marais)	4,900,000	80	4,900	Postoperative weight, +4 pounds (1.8 kg.); 15 months postoperative, patient very well (normal bleeding and clotting time)
.....	—	2,000,000	30	5,800	.....	.....	..	.....	Died of hemorrhage from mouth
—	—	1913-4,200,000 1922- 740,000	75 12	5,800 2,400	Arsenic Calcium chlorid	.....	..	.....	Spontaneous fracture left humerus (normal fragility and clotting time); died of pneumonia and pericarditis
—	..	4,000,000	62	11,800	.....	.....	..	.....	Necropsy of sister done, but pathologist refused to make a definite diagnosis; died of hemorrhagic pachymeningitis
—	—	Normal		Leukopenia	Splenectomy (Armstrong)	.....	..	.....	One month postoperative, better color; liver smaller
—	..	4,100,000	64	3,900	.....	.....	..	.....	Diagnosis by splenic puncture (normal fragility, bleeding and clotting time)
Small axillary	..	1,070,000	28	14,400	Arsenic	.....	..	.....	Died of acute edema of lungs
—	—	3,520,000	55	4,200	Splenectomy (Mixter)	.....	..	.....	Died 11 days postoperative of peritonitis
One gland left axilla	—	3,328,000	65	4,400	Splenectomy (Cheever) radiotherapy	4,200,000	..	13,100	Ten months postoperative, biopsy on enlarged cervical glands showed "Gaucher" cells (normal fragility)
Moderate axillary and inguinal	—	2,560,000	55	14,000	Splenectomy 1913 (Denver)	.....	..	.....	Pathologic fractures of left femur; died 10 years postoperative
—	—	5,144,000	90	5,000	Splenectomy (Whipple)	4,700,000	85	15,000	Postoperative weight, +8 pounds (3.6 kg.); 68 months postoperative, patient more pigmented; felt tired
—	—	1,300,000	23	2,900	Splenectomy (Whipple)	3,384,000	70	8,900	Postoperative gain in weight; blood cholesterol 0.21%; 3 months postoperative, better color; no bleeding; erosion of head of femur

w umbilicus; +++, 5 cm. below costal margin to umbilicus; ++, less than 5 cm. below costal margin, and +, edge palpable.

red stain with hematoxylin and eosin, and was covered with fine, anastomosing, darker lines (giving it the so-called "wrinkled" appearance). Many of the cells contained more or less of a dark brown granular pigment which gave the reaction for iron. None of them showed any vacuoles, nor was there any substance within them which took the scharlach r stain. The latter was not made on fresh tissue but after a few days of fixation in formaldehyd.

These cells were scattered all through the pulp, but in general they had a tendency to fill and distend the splenic sinuses. Many of them appeared as if free within the sinuses among the red blood cells. In many places they approached closely the adventitia of the pulp and corpuscle arteries and capillaries, but these were everywhere intact. In no place could the large cells be seen to encroach on the endothelium.

The general architecture of the spleen was preserved and was simply distorted by the presence of these large cells. The splenic corpuscles were quite small; the lymphoid tissue was scanty, and they were very widely separated by the presence in the pulp of the large cells. The pulp, aside from

the large cells, was apparently unchanged. In view of the size of the spleen there was an astonishingly small amount of fibrous tissue in the pulp, as demonstrated by the van Giesen stain. The trabeculae were not thickened.

The lymph node from the hilum showed a small group of the large cells among the lymphoid cells of the node, at one point just beneath the marginal sinus.

The general impression that one obtained from a study of this spleen was that the enlargement had been due almost exclusively to the presence of the large cells in the pulp and that these cells, from their situation, were much more apt to be reticulum cells than they were to be endothelium.

The relative proportion of cholesterol expressed in milligrams per gram of dried spleen was determined for us by Dr. L. Bauman, using a method modified from that of V. C. Myers and E. Wardell for determining the cholesterol in feces (J. Biol. Chem. **36**:147, 1918). For comparison the cholesterol was also determined in the spleens of a young man dying of lysol poisoning, of a syphilitic patient with a large fibrous spleen, and of a patient with hemorrhagic purpura. The lysol poisoning spleen was fresh; the other three had been preserved in 4 per cent. formaldehyd. The results were:

Gaucher's disease.....7.63 mg. per gram of dried spleen
Syphilitic spleen.....6.5 mg. per gram of dried spleen
Lysol poisoning spleen.....From 10.11 to 10.99 mg. per gram of dried spleen
Hemorrhagic purpura spleen..6.23 mg. per gram of dried spleen

The publications of Epstein [4] and Lieb [5] appear to throw considerable light on the nature of the substance contained in the spleen in Gaucher's disease. Lieb has obtained evidence that the substance is kerasin, a cerebrosid formed by the linkage of lignoceric acid, sphingosin and galactose. It was extracted from the dried spleen with alcohol and precipitated from the alcohol solution with mercuric chlorid. The cerebrosid appears in the filtrate after removal of the mercury with hydrogen sulphid. Lieb hydrolyzed the substance with sulphuric acid in methyl alcohol and obtained the methyl ester of lignoceric acid which, when cooled, he identified by melting point determination and analysis. In the filtrate from the ester, he isolated characteristic derivatives of sphingosin and galactose.

Following the procedure outlined by Lieb, Dr. Bauman was able to obtain almost 16 per cent. of crude "cerebrosid" from the alcohol extract of dried Gaucher spleen by mercuric chlorid precipitation. The substance was hydrolyzed with sulphuric acid in methyl alcohol and a substance obtained which agreed in properties and melting point with the methyl ester of lignoceric acid. It was not possible to identify sphingosin and galactose but this was probably owing to the small amount of material originally taken in work.

The patient had an uneventful recovery and was discharged on the twenty-third postoperative day. Her red blood cell count was 3,700,000, and the hemoglobin was 70 per cent. (Tallquist). A roentgen-ray examination of the hip showed the changes previously described, and it was thought to be an atypical neurotrophic joint. Examination of the eyes after operation showed the yellow, wedge-shaped conjunctival thickening that had been previously overlooked.

Two months after operation, the patient had gained 17½ pounds (7.9 kg.). Her color was better, and she was feeling very much improved. The red blood cells totaled 3,910,000.

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4. Epstein, E.: Biochem. Ztschr. **145**:398, 1924; Virchows Arch. f. path. Anat. **153**:1157, 1924.

5. Lieb: Ztschr. f. physiol. Chem. **140**:305, 1924.

Three months after operation, she was very well and had gained weight. Her color was good, and there was less pigmentation of the skin. The wedge-shaped yellow areas in the conjunctivae were less noticeable. The liver was not enlarged. The tendency to bleed from the gums had ceased. The red blood cells totaled 3,380,000; the white blood cells, 8,900. There was marked achromia. Several normoblasts were seen. The oxygen hemoglobin determination was 44.8 per cent. The blood cholesterol was 0.21 per cent. Roentgen-ray examination of the hip showed no change in the appearance. It still looked like a neurotrophic joint.

The patient went to the Orthopedic Hospital and was operated on by Dr. B. P. Farrell, Dec. 26, 1924. The head and neck were resected and the sequestrums were removed from the acetabulum. The capsule of the hip was greatly thickened and scarred. The neck of the femur was rounded off at

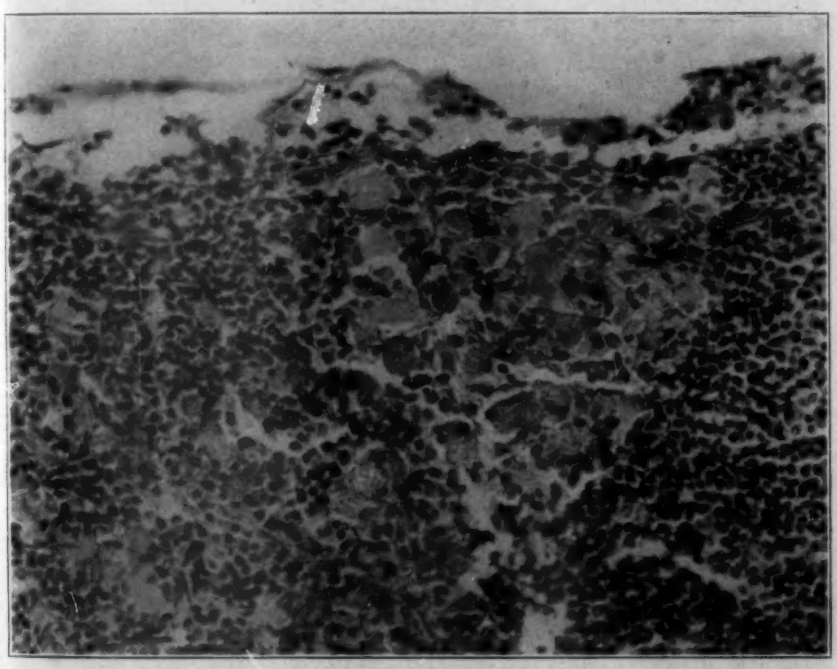

Fig. 8 (Case 2).—Lymph node from hilum of spleen, showing large cells lying in the lymphoid tissue immediately beneath the marginal sinus.

its end and was in the upper part of the acetabulum, the roof of which was eroded. There was no synovial membrane, and practically all the tissue seen was dense and fibrous. There were about six loose sequestrums in the wall of the acetabulum, all with a rough, granular surface. The neck of the femur was quite soft, and the bone seemed sandy and granular in consistency.

Examination of gross specimens, which consisted of the head and neck of the femur with some adherent fragments of the capsule and a few fragments from the acetabulum, showed the bone everywhere quite soft; in most places it could be cut with a knife. The marrow spaces were quite wide, and the marrow had a pale pink tinge. Very little of the articular cartilage remained on the head. The cartilage present was patchy and of unequal thickness, so

that in several places bare bone was exposed. The fragments of the capsule did not seem much, if any, thickened. Unfortunately the fragments from the acetabulum were mixed in with the other pieces so that it was impossible to be sure which they were.

Microscopic examination of unstained smears made from the fresh bone marrow at the time of operation showed many large bodies the size of Gaucher's cells. These looked like fat droplets except that they were not perfectly rounded and did not have refractile margins. When stained with alkaline methylene blue they took the stain readily, and it was at once apparent that they were Gaucher's cells and that they must be in great numbers, because no other types of cells could be seen.

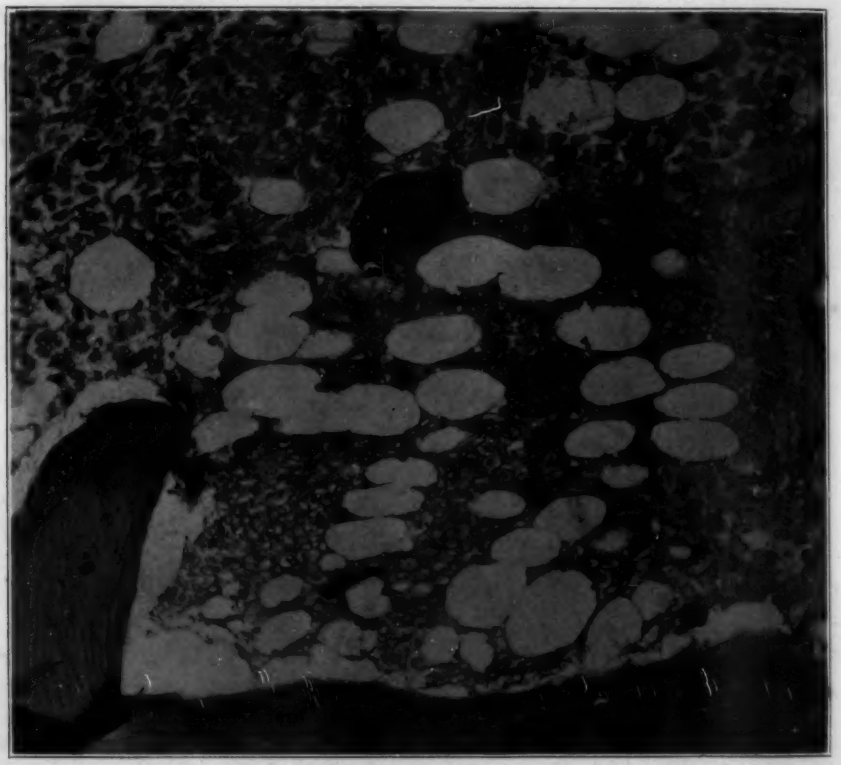

Fig. 9 (Case 2).—Massing of large cells in the bone marrow of the head of the femur, under low power.

Sections were prepared from five different bone fragments. They all decalcified readily in 5 or 10 per cent. nitric acid solution in twenty-four hours. The stained sections showed a wide spacing of bone trabeculae which appeared rather thin and which, to judge by the ease with which they could be cut with the knife, must have contained a diminished amount of calcium. In all the pieces the marrow spaces were loaded with the characteristic Gaucher's cells. An occasional fat cell could be found as well as a very delicate connective tissue stroma and a moderate number of blood vessels. But one had to search a long time before finding any of the usual cells characteristic of bone marrow.

The Gaucher's cells impressed one as being very tightly packed in many places, so that many of them were elongated and narrowed instead of being round. Near the joint surface fragments of cartilage remained and the destruction of bone seemed greatest at this point. Sections of the capsule showed nothing except in some parts a few phagocytic cells containing blood pigment. No large cells were found anywhere outside the bone. No trace of any other lesion, such as tuberculosis, could be found.

It does not seem possible to explain this lesion as due to any other cause than the multiplication of Gaucher's cells within the bone marrow resulting in gradual atrophy of the head of the femur, erosion of the articular cartilage of both the femur and the acetabulum and gradual disintegration of the joint.

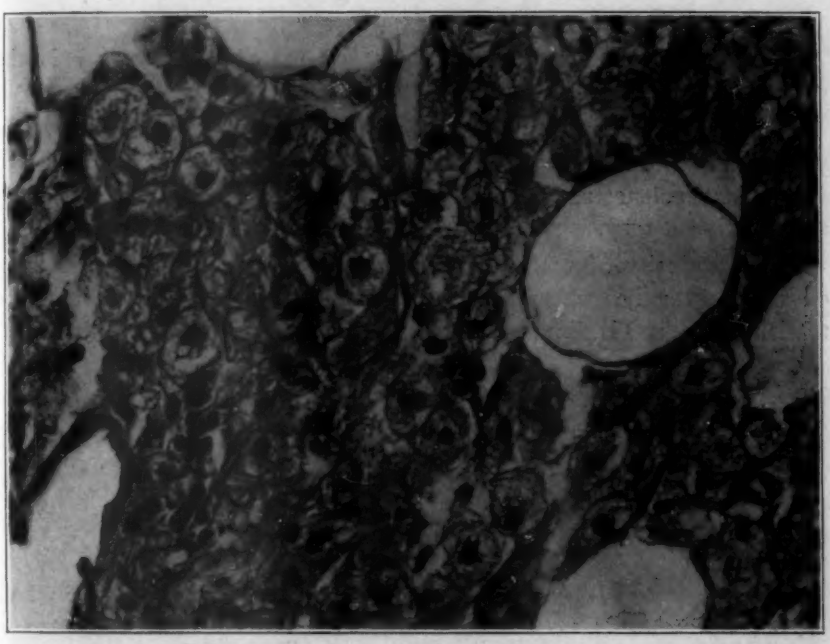

Fig. 10 (Case 2).—Large cells in the bone marrow, showing morphologic characteristics; wavy lines passing through the cytoplasm in different planes are clearly shown. The large spaces to the right are fat cells. In the lower left-hand corner is a capillary (photomicrograph × 800).

While we cannot be sure that the marrow on the acetabular side was filled with Gaucher cells, it seems probable that it was because all the pieces of bone examined showed involvement.

She made an excellent operative recovery and was discharged in a month. When last seen, eight months after the first operation, she was not feeling as well as she had been before the joint operation. Roentgen-ray examination showed rarefaction in the lower part of the femur and in the acetabulum. Red blood cells totaled 2,800,000; white blood cells, 13,200; hemoglobin, 85 per cent.; polymorphonuclears, 61 per cent.; leukocytes, 30 per cent., and mononuclears, 9 per cent.

SUMMARY

The study made of the two new cases of Gaucher's disease reported in this paper has not clarified our views as to its etiology.

It has been shown that there was a considerable proportion of the cerebrosid kerasin in the spleen of one of these patients; this confirms the work of Lieb and Epstein. It seems reasonable to suppose that this substance is contained within the cytoplasm of the Gaucher cells.

It has been demonstrated that the presence of the large cells in the bone marrow of the head and neck of the femur may result in a marked destruction of bone and produce a chronic ostearthritis with sequestrum formation.

Of the various types of treatment attempted, splenectomy is the only one that has been attended with any measure of success.

We feel that there is no indication that the disease is cured by this procedure. It is our opinion that enough evidence does not exist to show that splenectomy actually prolongs life although the figures suggest that it may.

In a majority of cases, splenectomy does result in an amelioration of symptoms; the general health and strength are improved, and the tendency to bleed is diminished.

FIBROSARCOMA OF THE THYROID*

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According to Ewing,[1] the occurrence of true sarcoma of the thyroid gland still requires demonstration, and in a review of the literature it is quite evident that tumors of the thyroid have been classified as sarcoma merely because of the presence of spindle cells or round cells without the application of any more accurate criteria of diagnosis. Since the age of incidence, clinical course, gross anatomic appearance and mode of extension are quite similar in carcinoma and sarcoma of the thyroid, only the histologic distinctions between the two remain. Confusion in microscopic diagnosis frequently occurs owing to the fact that it has not been fully appreciated that the cells of a carcinoma of rapidly proliferating type assume an undifferentiated form superficially resembling in morphology the cells of a fibrosarcoma or lymphosarcoma; unless the arrangement of the cells is carefully studied in various parts of the tumor and special staining methods employed to distinguish the fibrils of cells of connective tissue origin, many of these tumors are erroneously placed in the class of sarcoma.

Although this article is limited to fibrosarcoma, under which class the case reported falls, the same general facts are true of cases of so-called round cell or lymphosarcoma, most of which will be found on careful analysis to be merely undifferentiated epithelial growths of the thyroid. That fibrosarcoma of the thyroid is not nearly as frequent as reported is quite true, but there are undoubtedly authentic cases and there is no reason why a neoplasm should not arise from the connective tissue elements of the thyroid as from that of any other organ.

In reviewing cases described in the older literature, it is particularly hard to arrive at a fair judgment as to their authenticity. With such a rare tumor as sarcoma of the thyroid, the burden of proof lies on the author and the evidence is often lacking. Instead of photomicrographs, illustrations often are made diagrammatically to convey the conviction of the author, and the verbal descriptions often are vague and incomplete. Many cases reported as sarcoma are described chiefly for the clinical and surgical aspects of the case with no intention of establishing the accuracy of the pathologic diagnosis.

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1. Ewing, J.: Neoplastic Diseases, Ed. 2, Philadelphia, W. B. Saunders Company, 1922.

Kaufmann [2] in 1879 reviewed the cases of malignant tumors of the thyroid described in the older literature and his is the earliest analysis that is of any value. Ehrhardt [3] in 1902 and Müller and Speese [4] in 1906 wrote lengthy reviews and discussions of cases of malignant tumors of the thyroid up to date. They have in most instances accepted the diagnoses of those who described the cases, whereas it seems that the evidence is lacking for many of these. A paper by Wilson [5] in 1921 gives a bibliography of malignant tumors of the thyroid which includes cases omitted by Müller and Speese and all reported cases between 1906 and 1921, but does not give a critical analysis of these cases.

In an examination of reported cases it seems that a skeptical attitude is warranted. In view of our present more accurate criteria of diagnosis, we should demand more concrete evidence of the derivation of a tumor or else we will become disoriented in our ideas of the histogenesis of tumors. Reviewing then the chief cases in the literature reported as spindle cell or fibrosarcoma, they fall under three heads: cases in which evidence is completely lacking; doubtful cases, in which evidence is incomplete, and those presumably authentic.

Cases in which proof is lacking are those in which description of the microscopic appearance of the tumor is slight, often a mere statement being made that the cells were fusiform; the interest is usually in the clinical aspects of the case. Illustrations are usually absent or inadequate. Among these are cases reported by Berry,[6] Botella,[7] Chifoliau and Masson,[8] Cumston,[9] Doléris,[10] Gatti,[11] Goris,[12] Heath,[13] Klun-

2. Kaufmann: Die Struma maligna, Deutsch. Ztschr. f. Chir. **11**:400, 1879.

3. Ehrhardt, O.: Zur Anatomie und Klinik der Struma maligna, Beitr. z. klin. Chir. **35**:343, 1902.

4. Müller, G. P., and Speese, J.: Malignant Disease of the Thyroid Gland, Univ. Penn. M. Bull. **19**:74, 1906-1907.

5. Wilson, L. B.: Malignant Tumors of the Thyroid, Ann. Surg. **74**:129 (Aug.) 1921.

6. Berry, J.: Diseases of the Thyroid, London, 1901.

7. Botella, E.: Fibro-sarcome de l'Isthme et du Lobule droit de la Gland thyroide, Arch. internat. de laryngol. **20**:91, 1905.

8. Chifoliau and Masson: Epithélio-sarcome du Corps thyroide, Bull. et mém. Soc. anat. de Paris **84**:357, 1909.

9. Cumston, C. G.: Sarcoma of the Thyroid Gland, Phila. Month. M. J., 1899, p. 277.

10. Doléris, A.: Sarcome primitif du Corps thyroide, Bull. Soc. anat. de Paris **51**:225, 1876.

11. Gatti, G.: Rapide Développement d'un Sarcome de la Thyroide, Rev. de chir. **15**:618, 1895.

12. Goris: Sarcome thyroidien, J. de chir. et ann. Soc. belge de chir. **8**:370, 1908.

13. Heath: Spindle Celled Sarcoma of the Thyroid, Involving Larynx, Secondary Deposits, Death, M. Times & Gaz. **2**:663, 1879.

zinger,[14] Kobler,[15] Kreglinger,[16] Moore,[17] Nadal,[18] Papin and Saboréanu,[19] Porter,[20] Shattuck,[21] Simpson,[22] Van der Veer,[23] Jones and Brattle [24] and Braun.[25]

The second group, doubtful cases, are those which are more thoroughly described but which lack convincing microscopic description, or in which it is questionable whether the primary tumor was in the thyroid. It is not intended to dispute the authenticity of these but the evidence that is submitted seems decidedly inadequate from a pathologic standpoint. In this group are included cases reported by Bassal and Rigaud,[26] Binnie,[27] Bowlby,[28] Ehrhardt,[3] Förster,[29] Herren-

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14. Klunzinger: Carcinom und Sarkom in einer Schilddrüse, Zentralbl. f. allg Path. u. path. Anat. **24**:967, 1913.

15. Kobler, G. V.: Sarkom der Schilddrüse mit multiplen Hirnhämorrhagien, Wien. med. Wchnschr. **36**:295; 344, 1886.

16. Kreglinger: Zur Kenntnis der primaren Sarkome der Schilddrüse mit seltenen Metastasen, Arch. f. klin. Chir. **111**:545, 1919.

17. Moore, N: Primary New Growth in Thyroid, Tr. London Path. Soc. **37**:513, 1886.

18. Nadal, P.: Sarcome à myeloplaxes du Corps thyroides, Bull. et mém. Soc. anat. de Paris **85**:736, 1910.

19. Papin and Saboréanu: Sarcome du Corps thyroide, Bull. et mém. de la Soc. anat. de Paris **79**:533, 1904.

20. Porter, M. F.: Coexisting Infection and Sarcoma of the Thyroid, Ann. Surg. **57**:501, 1913.

21. Shattuck, S. G.: Hypertrophy of an Accessory Thyroid in a Case of Spindle Celled Sarcome of the Thyroid, Tr. Path. Soc. London **39**:339, 1888.

22. Simpson, B. T.: Pathology of Goiter Based upon Specimens Received at the State Institution for the Study of Malignant Disease, Buffalo, N. Y., Surg., Gynec. & Obst. **28**:153 (Feb.) 1919.

23. Van der Veer, E. A.: Report of a Case of Sarcoma of the Thyroid, Ann. Surg. **46**:829, 1907.

24. Jones, S., and Battle, W. H.: Sarcoma of the Thyroid Gland, St. Thomas' Hosp. Rep. **18**:233, 1888.

25. Braun, H.: Beiträge zur Kenntnis der Struma Maligna, Arch. f. klin. Chir. **28**:291, 1882.

26. Basal, L., and Rigaud: Sur un cas d'épithélio-sarcome du corps thyroide, Arch. de méd. expér. et d'anat. path. **25**:491, 1913.

27. Binnie, J. F.: Malignant Neoplasms of the Thyroid with Metastases in the Intestine and in Bone, Surg., Gynec. & Obst. **26**:288 (March) 1918.

28. Bowlby, A. A.: Infiltrating Fibroma (Sarcoma?) of the Thyroid Gland, Tr. Path. Soc. London **36**:420, 1885.

29. Förster: Ueber die Geschwülste der Schilddrüse, Würzb. med Ztschr. **1**:24, 1860.

schmidt,[30] Kaufmann,[2] Kummer,[31] Lartigau,[32] Limacher,[33] Reverdin,[34] Schiller,[35] Vandenberg [36] and Wilson.[5]

The only cases in the accessible literature which seem at all convincingly authentic are those reported by Wölfler,[37] who describes three cases with metastases verified by necropsy, which, though accompanied by very diagrammatic drawings, have careful descriptions of the microscopic appearance; a case of Müller and Speese,[4] with necropsy findings; one of Tiffany and Lanier,[38] which has a careful description of the surgical specimen, although no necropsy was done and the illustrations are diagrammatic, and a case of Saltykow,[39] with an adequate microscopic description and in which necropsy showed metastases.

The case reported here seems worthy of consideration because of the rareness of its type, the interesting clinical history and the unusual gross and microscopic character of the tumor.

REPORT OF CASE

History.—A man, aged 61, had been under observation from time to time over a period of three years. His general physical condition had been good. On the last admission his chief complaint was loss of voice and cough of several weeks' duration. His temperature fluctuated between 100 and 101 degrees. There was continual coughing with production of abundant sputum, which was negative for tubercle bacilli. The neck was thick and short but on physical examination there were no palpable masses in the neck. There were impaired resonance over the left base, increased breath sounds and fine moist râles. Roentgen-ray examination of the chest showed large circumscribed areas of increased density interpreted as metastatic tumors throughout both lungs.

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30. Herrenschmidt, A.: Sarcome massif du corps thyroid avec noyan épithéliomateux ceexistant et particulaité de structure de sarcome, Bull. et mém. Soc. anat. de Paris **82**:300, 1907.

31. Kummer, E.: Sarco-adénome du corps thyroide, Rev. méd. de la Suisse Rom. **18**:702, 1898.

32. Lartigau, A. J.: Primary Sarcoma of the Thyroid Gland, Am. J. M. Sc. **122**:156, 1901.

33. Limacher, E.: Ueber Blutgefässendotheliome der Struma, Virchows Arch. f. path. Anat. **151**:113, 1898.

34. Reverdin, J. L., and Buscarlet, F.: Goitre néoplasique suffocant, Rev. méd. de la Suisse Rom. **17**:764, 1897.

35. Schiller, A.: Ueber die Kropfoperationem an der Heidelberger Klinik in den Jahren 1888-1898, Beitr. z. klin. Chir. **24**:535, 1899.

36. Vandenberg, H. J.: Report of a Case of Sarcoma of the Thyroid, J. Michigan M. Soc. **16**:18 (Jan.) 1917.

37. Wölfler, A.: Ueber die Entwickelung und den Bau des Kropfes, Arch. f. klin. Chir. **29**:754, 1883.

38. Tiffany and Lanier: Primary Sarcoma of the Thyroid Gland, Ann. Surg. **26**:498, 1897.

39. Saltykow: Ueber das Gleichzeitge Vorkommen des Sarkoms und des Carcinoms in der Schilddrüse, Zentrabl. f. allg. Path. u. path. Anat. **16**:547, 1905.

Some time after admission, an enlargement of the neck was noted, and this grew in size with remarkable rapidity. It presented as a hard spherical mass about 2 inches (5 cm.) in diameter, fixed in position, and lying in close relation to the right sternomastoid muscle, with the overlying skin red and hot. He complained of severe pain starting from this tumor and radiating upward. He could speak only in a whisper. No tumors could be found in the nasal or buccal cavities and laryngeal examination revealed no tumor of the larynx. He rapidly became weaker, and developed marked difficulty in swallowing and in respiration. A month after admission he had a stabbing pain in the chest, followed by physical signs of consolidation of the left lung. Dyspnea became urgent and death occurred six weeks after admission.

Necropsy.—Postmortem examination was made five hours after death. The important findings were: malignant tumor of the thyroid with metastases to regional lymph nodes, lungs and liver; lobar pneumonia and acute fibrinous pleuritis of the left lung; hydrothorax; hydropericardium; stenosis and erosion of the esophagus by tumor; arteriosclerotic nephritis; generalized arteriosclerosis; edema of the brain, and calcification of the falx.

Gross Appearance.—The neck was greatly enlarged by a hard nodular tumor mass in close relation to the right sternomastoid muscle, about 6 cm. in diameter, fixed to the deeper structures and not adherent to the skin. On dissection, the tumor was found to lie directly under the sternomastoid, and to be intimately connected with it. This mass was continuous with tumor tissue occupying the position of the thyroid, and extended downward beneath the right clavicle along the trachea as far as the bifurcation. The tumor was dissected away from the skin and removed as a whole, together with the larynx, trachea and tongue, which altogether weighed 630 gm. The tumor itself measured about 15 by 8 by 5 cm.

The tumor had a lobulated structure and was very firm in consistency. On section it was composed of numerous coalescing islands of firm tissue, the margins of which appeared as pale translucent bands bulging from the cut surface, while the centers appeared as depressed yellow areas, scirrhous in character and often studded by small yellow necrotic foci. The common, internal and external carotid arteries and internal jugular vein of the right side were completely embedded in tumor tissue.

The main mass of tumor extended along the right side of the trachea and larynx. The thyroid cartilage was covered by smaller nodular masses of tumor quite similar to the tumor tissue elsewhere but not so bulky and more or less preserving the general contour of the normal thyroid gland. On section, however, no recognizable thyroid tissue remained, the gland being completely replaced by tumor.

The internal aspects of the larynx and trachea showed no important lesions. The esophagus was encroached on by two tumor nodules which projected into the lumen and distorted the course of the esophagus in its middle third. At a level 5 cm. above the bifurcation of the trachea, the tumor had eroded through all walls of the esophagus and presented an ulcerating surface on the mucosa.

Metastases in Lungs: The lungs showed bulky spherical tumor masses measuring up to 9 cm. in diameter (Fig. 1). These usually bulged from the pleural surfaces as hard white nodular areas. On section the tumor tissue was for the most part white and spongy in character, riddled with many small areas of necrosis which gave the centers a moth-eaten appearance. The peripheral zone of tumor tissue was firm, gray and translucent and resembled the tumor tissue in the neck, though some areas were bright orange. In many nodules, especially the larger ones, necrosis was so extensive that the entire center was composed

of a cavity filled with thick cloudy white fluid mixed with sticky mucoid material and surrounded by merely a shell of tumor tissue. One of these large necrotic metastases had ruptured through the pleural surface and emptied its contents into the pleural cavity. The pleural surface here was covered with fibrinopurulent exudate.

The left lung was especially involved with metastases, the lower lobe being almost completely replaced by massive tumor growths. What pulmonary tissue

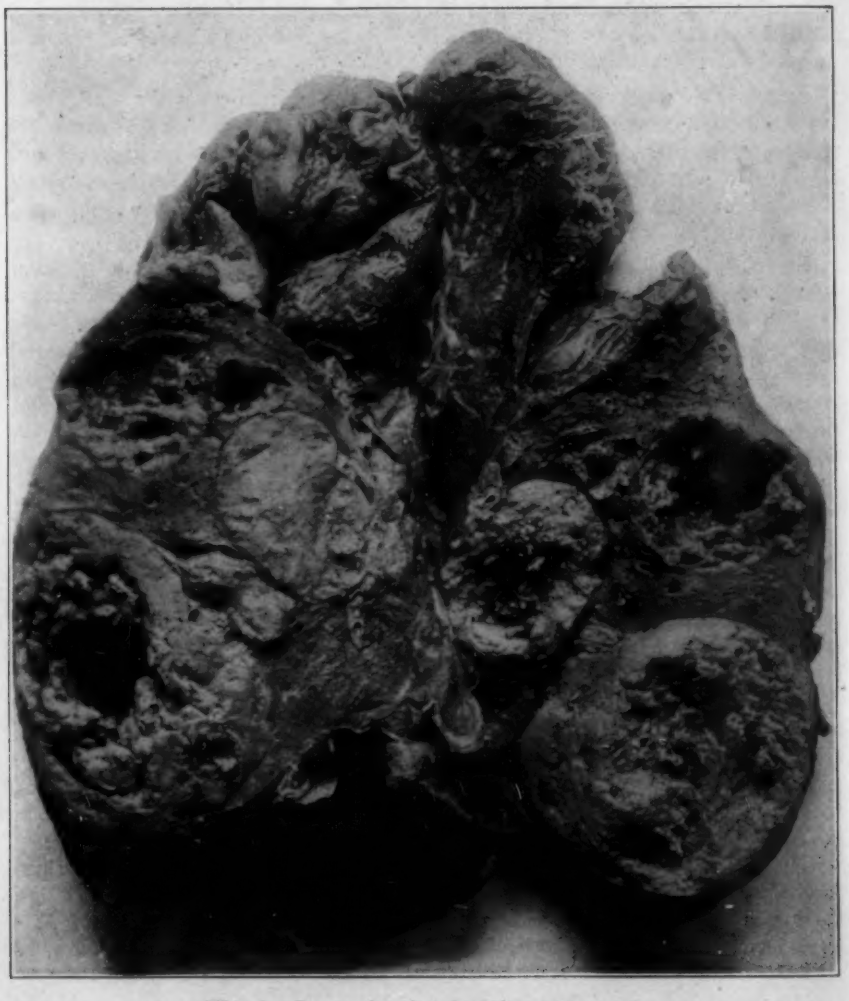

Fig. 1.—Lung showing massive metastases.

remained in the lower lobe and the pulmonary tissue of the entire middle lobe was gray, granular and consolidated. The right lung weighed 730 gm., the left 1,300 gm.

Metastases in Liver: A few punctate tumor metastases occurred on the capsular surface of the liver, the largest measuring 0.4 cm. in diameter.

Microscopic Appearance: The tumor was composed of oval and elongated cells, closely placed without orderly arrangement except the formation of whorls

(Fig. 2). Nowhere did it form islands or have any tendency to an alveolar arrangement. The individual cells varied considerably in size, but were predominatingly fusiform in shape (Fig. 3). The nuclei were usually large, oval and clear, with delicate chromatin reticulum. Where the tumor was growing rapidly, the nuclei were hyperchromatic, large and bizarre in shape, often lobulated and multinucleated (Fig. 4). Mitotic figures were very numerous. The cytoplasm

Fig. 2.—General arrangement of elongated tumor cells of fibroblastic type, under low power; a few persisting thyroid acini are surrounded by tumor cells; × 150.

was usually abundant and homogeneous. The cells invariably tapered off at both poles, terminating in delicate waving fibrils which were demonstrated best in sections stained by phosphotungstic acid hematoxylin. Only a very delicate collagen deposit separated adjacent cells.

Necrosis and hemorrhage were extensive. In several areas where necrosis was marked, a striking picture was presented by large accumulations of multinucleated giant cells. These cells were huge masses of undivided cytoplasm in which often as many as 100 nuclei could be counted. The cytoplasm of these cells often showed globular inclusions. They bore a striking resemblance to the giant cells of bone tumors of the epulis type. They occurred where the tumor was of rapidly proliferating type, always in association with areas of necrosis, and appeared to be tumor giant cells with phagocytic activity.

Only a small amount of thyroid tissue remained, and this showed acini of usual size containing a moderate amount of colloid. The connective tissue stroma

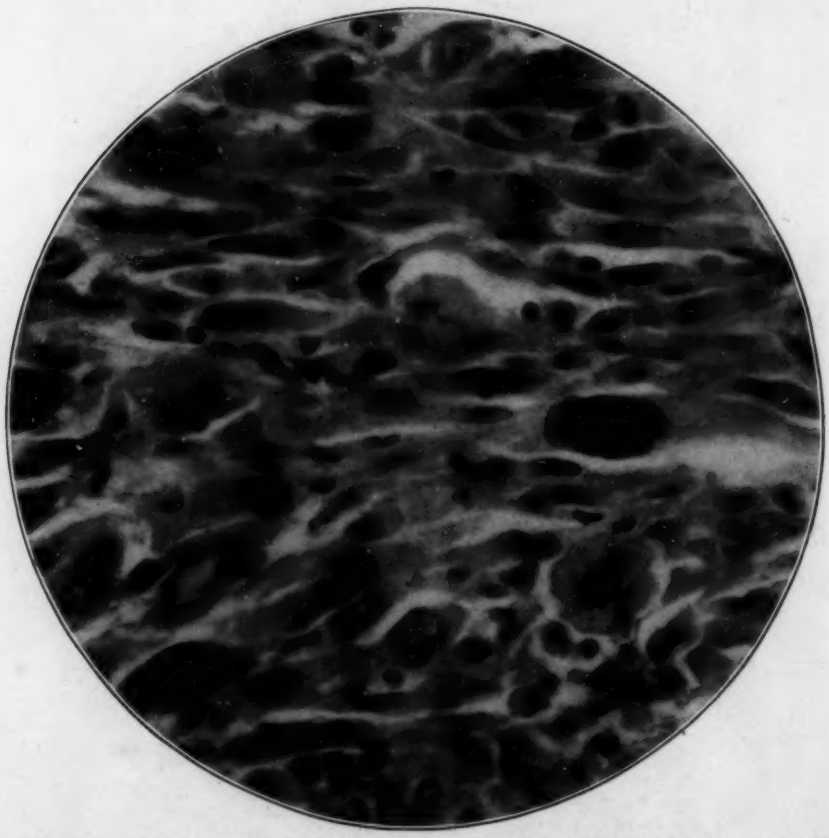

Fig. 3.—Fusiform cells with large, irregular nuclei, under high power; × 600.

was increased and throughout it were scattered lymphocytes. There was a gradual transition from healthy thyroid to tumor tissue. The fusiform tumor cells appeared to be definitely arising from the stroma of the thyroid. In the transition zone thyroid acini were widely separated by a cellular stroma that faded off indistinguishably on one hand to tumor cells, and on the other hand to mature connective tissue stroma. As one progressed further away from healthy thyroid, the acini occurred only at intervals separated widely by fusiform tumor cells, and where they were persisting they were lined by flat or cuboidal epithelial cells surrounding a large lumen (Fig. 2). Nowhere did the epithelial cells show

hyperplastic tendencies. They were distinctly passive structures, being surrounded by cells of connective tissue type.

In the lungs, the tumor cells were of the usual spindle form with occasional giant multinucleated forms. In many places tumor cells filled the alveoli without destroying to any extent the alveolar walls, so that the general architecture of the pulmonary tissue was preserved. More often, however, necrosis was extensive, involving both pulmonary tissue and tumor cells.

In the liver, the tumor cells were of spindle form. In the periphery of the metastatic growth individual tumor cells lay within the liver sinusoids without greatly distorting the structure of the hepatic lobule.

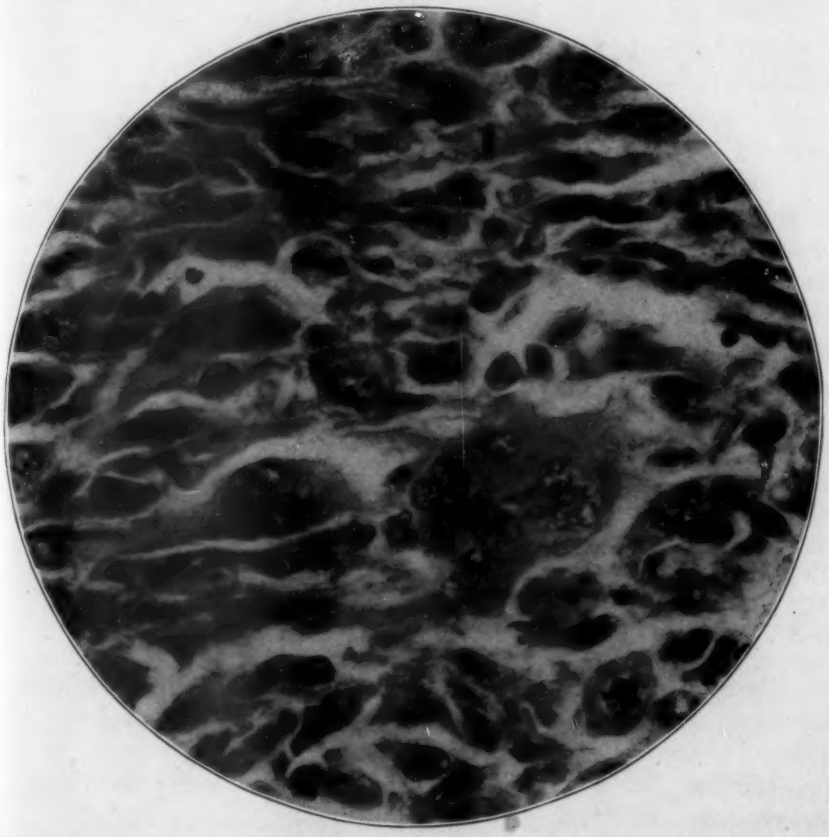

Fig. 4.—Large multinucleated tumor cells and fibrils, under high power; × 600.

The clinical features of interest in this case are the extremely rapid growth of the tumor, the involvement by pressure of the recurrent laryngeal nerve with resultant aphonia even before the tumor was noticeable, and the extremely bulky metastases in the lungs. Difficulty in determining the primary site of the tumor during the patient's lifetime was offered by the fact that the tumor had extended so far to the lateral aspect of the neck, while the main portion of the thyroid was

relatively small. Its location seemed more consistent with carcinoma of the cervical lymph nodes secondary to a primary carcinoma in the nasopharynx or larynx, except that no such primary tumor could be found.

The most interesting features of this case were the microscopic. In a malignant tumor of the thyroid, the problem of determining whether the cells are of epithelial or fibroblastic origin is an especially perplexing one, as tumors of this organ tend to be highly malignant and the cells in consequence are of undifferentiated type and show few morphologic features distinguishing them as epithelial or fibroblastic by ordinary staining methods. However, in a rapidly growing carcinoma that assumes the aspect of a sarcoma in the undifferentiated character of its cells, there can nearly always be found a less rapidly growing portion in which the cells show their true identity as epithelial in character in their arrangement in islands, alveoli or glands. In the present tumor, however, although many sections were cut, none of the cells had any resemblance to cells of epithelial derivation. Moreover, in a thyroid carcinoma in which portions of normal thyroid persist, transitions can be seen between tumor cells and hyperplastic epithelial cells, while in the present case, the epithelial cells of the persisting thyroid were not at all hyperplastic and were distinctly passive structures.

Important criteria for distinguishing between epithelial and fibroblastic tumors are the presence of stroma in the former and the presence of fibrils and the production of intercellular substance in the latter. In this tumor no stroma was present, and on application of the phosphotungstic acid hematoxylin stain for indisputable evidence of fibroblastic origin, each cell was seen to terminate in a delicate fibril and to be forming intercellular substance.

SUMMARY

The case described of fibrosarcoma of the thyroid gland showed extremely rapid growth, involving the recurrent laryngeal nerve and producing massive metastases in the lungs.

Proof of the fibroblastic origin of the tumor was offered by the demonstration of fibrils by histologic methods.

GASTRIC MOTILITY

I. THE ORIGIN AND CHARACTER OF GASTRIC PERISTALSIS *

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METHODS

The original purpose of this study was to ascertain the effects of the various surgical procedures on the character of gastric peristalsis and the motility of the stomach. Various possible methods of study presented themselves:

First, observation of the stomach by means of the roentgen ray following the operation, and comparison with the normal.

Second, the insertion of a balloon into the stomach and the study of the gastric waves as transmitted by the balloon and recorded on a smoked drum after the various operations.

Third, observation of the stomach in situ through a laparotomy incision after surgical operation at an earlier date, and

Fourth, excision of the stomach in toto and suspension in a warm bath of Ringer's solution.

The third method was selected because it furnished direct visual evidence of the phenomena that were taking place, and because it afforded more normal conditions than the last method. It was also planned to make concurrent studies with the roentgen rays.

After some of the early experiments it became evident that the motor phenomena of the stomach under the conditions of these experiments did not entirely agree with the conception of them held by many physiologists. It was therefore decided to confine this work to the study of normal gastric peristalsis and the pylorus. These experiments were completed in 1922, but owing to illness could not be reported sooner.

It is known that a laparotomy usually causes a cessation of peristaltic activity due to the reflex inhibitory impulses that are set up. To overcome that difficulty, Auer [1] suggested sectioning one or both groups of extrinsic nerves. Because of the ease with which vagus section may be performed, that procedure was decided on for this work. The objections that may be raised against the method will be considered presently.

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1. Auer, J.: The Course of the Contraction Wave in the Stomach of the Rabbit, Am. J. Physiol. **23**:165, 1908-1909.

Only dogs were used in the experiments. At first the vagi were sectioned in the neck. Nearly all these animals died of bronchopneumonia, probably following the paralysis of the laryngeal muscles. One of these animals was alive two weeks after the date of sectioning, but was vomiting nearly all the food he ate, owing to a paralysis of the esophageal muscles. For these reasons vagus section in the neck was abandoned and the nerves were divided just as they emerged through the diaphragm.

The nerves are easily reached through a high midline incision. If the lesser curvature is put on the stretch, they are felt as two firm, unyielding cords on either side of the curvature. The section was performed as high up as possible in order to reach a point above that at which the branches are given off. Even so, later necropsies occasionally showed that a branch was given off in the chest and that this branch, passing down independently of the main trunks, had not been severed. As this work was not concerned with the effects of vagus section but rather with motility, such an occasional finding did not vitiate the results. Postmortem examination was always performed and among other things the vagus section was noted.

As some authors have reported ulcers following vagus section, I incidentally state that there was not the slightest indication of a lesion comparable to an indurated ulcer in any of the animals.

Twenty-five healthy animals were examined after vagus section. In two of these, bilateral section had been performed in the neck; in two, unilateral section had been carried out in the abdomen, and in the remainder, both vagi had been severed at the level of the diaphragm. The operation had been performed in a much larger number, but the remainder developed distemper during several epidemics in the laboratory and were therefore discarded. In addition, sleeve resection was performed on two animals; a V resection of the reentrant angle on four, and an excision of a small area of the anterior gastric wall on two. In all the latter, bilateral vagus section also was done.

A transverse upper abdominal incision under light ether anesthesia was usually made one week after vagus section. The stomach was left in its natural surroundings. All exposed surfaces were kept moist by the continuous drip of physiologic sodium chlorid solution at body temperature.

It is difficult in the extreme to study organs experimentally and yet retain normal conditions. Nevertheless, even though the anatomy of an organ, for instance, is altered, it does not necessarily follow that all the experimental results obtained under such conditions are inapplicable to the normal organ. A dog equipped with a "Pawlow stomach" and a gastric fistula can hardly be said to possess a normal organ.

Yet the phenomenon of the appetite juice, which among others was firmly established by this experimental procedure, is by general consent held to be just as true for the intact stomach. Also, if one group of findings is confirmed by a second experimental procedure that is utterly different from the first, that confirmation lends added importance.

In this work an attempt was made to see the stomach while it was at work. The factors that had to be overcome were the inhibitions to the gastric motor phenomena due, first, to reflexes from the incised abdominal wall, and, second, to the emotions that would be aroused in the dog were he to feel and see the experimental procedures. To overcome the first difficulty, the vagi were incised, as has already been stated; to overcome the second, a light ether anesthesia just sufficient to abolish consciousness was used. Do the cut vagi, the ether anesthesia, and the exposure of the organs following the laparotomy render the results obtained inapplicable to normal conditions?

Our knowledge concerning the extrinsic nerves of the stomach is as yet incomplete, but one fact seems certain. We cannot regard the vagi as purely motor, and the splanchnics as purely inhibitory; both systems of nerves carry motor and inhibitory fibers. Thomas and Wheelon,[2] who give an excellent summary of the experimental investigations on the gastric extrinsic nerves, conclude from their own work that stimulation of the vagus leads to motor responses in about 90 per cent. of the trials, and to inhibitory responses on the pyloric sphincter in 10 per cent. In the case of the splanchnic nerves, stimulation leads to motor responses in 63 per cent. of the trials and to inhibitory responses in 37 per cent. In other words, under the conditions of their experiments motor phenomena were far more frequent following the stimulation of either system, and their work bore out the findings of others that the vagi did possess inhibitory fibers.[3]

What is more striking is the fact agreed to by many that the stomach may function with apparently little or no change following the division of either or both of the extrinsic systems of nerves. Thus Cannon[4] found that after severing the vagi in cats there was a temporary slowing of the gastric peristalsis and a lowering of tone, but that the

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2. Thomas, J. E., and Wheelon, H.: The Nervous Control of the Pyloric Sphincter, J. Lab. & Clin. Med. **7**:375 (April) 1922.

3. Cannon, W. B.: The Motor Activities of the Stomach and Small Intestine After Splanchnic and Vagus Section, Am. J. Physiol. **17**:429, 1906. Langley: On Inhibitory Fibers in the Vagus for the End of the Esophagus and the Stomach, J. Physiol. **23**:407, 1898. May, Page: The Innervation of the Sphincters and Musculature of the Stomach, J. Physiol. **31**:260, 1904. Marcacci, quoted from Luciani: Physiologie des Menschen. Jena, **2**:173, 1906.

4. Cannon (Footnote 3, first reference).

animals recovered from these effects within a few days. Auer [5] found in rabbits that a few days after section of the vagi or splanchnics, or both, the peristalsis is once more normal in rate, rhythm and strength. Borchers,[6] who observed the peristalsis in cats through a window in the abdominal wall, found that five days after vagus section the peristalsis was once more normal. Aldehoff and Von Mering [7] and Kirschner and Mangold [8] reached a similar conclusion, and May [9] reports vagotomy performed without lasting effect in rabbits, dogs, cats and apes.

In the majority of the experiments performed by me, the peristalsis was studied from seven to ten days after the section of the vagi. Peristalsis was present in spite of the abdominal incision in about three fourths of the dogs. It would seem that in these dogs the section of the vagi had removed a sufficient number of inhibitory fibers to permit the persistence of peristalsis even after laparotomy. Furthermore, the interval mentioned above was found to be the best. If a much longer period was permitted to elapse after vagus section, peristalsis was only very rarely seen after laparotomy. Perhaps that was due to the establishment of a compensatory action by the remaining inhibitory fibers of the splanchnics. However, as all these observations were made at a time when, according to all the authorities mentioned above, normal peristaltic relations had once more been established after the vagotomy, it appears to be fair to regard the motor phenomena that were found as closely similar to, if not the same as, those occurring under normal conditions.

Does the administration of a light ether anesthesia render the results inapplicable to normal conditions? The abdominal wall of the rabbit is quite thin, and if the abdominal hair is shaved the peristaltic waves may be seen to course down the stomach after a full meal. Auer,[10] utilizing that fact, made careful observations of this peristalsis. Certainly this method comes very close to nearly normal conditions. Besides

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5. Auer, J.: Effect of Severing the Vagi or Splanchnics or Both Upon the Gastric Motility in Rabbits, Am. J. Physiol. **25**:334, 1909-1910; Gastric Peristalsis in Rabbits Under Normal and Some Experimental Conditions, Am. J. Physiol. **18**:347, 1907.

6. Borchers: Anteil des Nervus Vagus an der motorischen Innervation des Magens im Hinblick auf die operative Therapie von Magenkrankheiten, Studien zur Physiologie und Pathologie der Magen Chirurgie, Beitr. z. klin. Chir. **122**: 547, 1921.

7. Aldehoff and Von Mering: Ueber den Einfluss des Nervensystemes auf die Funktion des Magens, Verhandl. d. Cong. f. inn. Med. **17**:333, 1899.

8. Kirschner and Mangold: Die motorische Funktion des Sphincter Pylori und des Antrum Pylori beim Hunde nach der querer Durchtrennung des Magens, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **23**:446, 1911.

9. May (Footnote 3, third reference).

10. Auer (Footnotes 1 and 5).

watching the course of the peristaltic waves, he made graphic records of them by placing a Marey receiving tambour on the pyloric third of the stomach. In addition to other work, the effect of the administration of an ether anesthetic was studied. With the exception of some irregularity at first, due to inhibitions set up from the nasopharynx during induction, he found that gastric peristalsis is "at least as regular as before the anesthesia. This regularity is maintained even when the corneal reflex is absent." Apparently, then, light ether anesthesia does not have any profound effect on gastric peristalsis. Certainly there is no evidence that it helps to create irregular types of waves. And the evidence presently to be advanced lends added support to these findings. Wheelon and Thomas [11] also found an ether anesthesia entirely satisfactory for their studies on the effects of stimulation of the extrinsic nerves.

Except when otherwise stated, the dogs were fed one-half hour before the observations. The meal totaled 400 c.c. In some of the later experiments different quantities were used and this is so stated. The meal consisted either of broth with meat and bones or of milk with or without bread.

Following the laparotomy for the study of the gastric peristalsis in the dogs, the exposed surfaces were kept continuously moist and warm with physiologic sodium chlorid solution. The edges of the wound were not widely retracted, but were held open only sufficiently to permit observation of the parts desired. Several dogs were studied while entirely immersed in a warm bath of physiologic sodium chlorid solution, but as this method did not seem to afford any added advantages, the former method was resorted to. The results reported are not at variance with findings obtained by other methods.

The discussion has been divided into the following parts:

I. The origin of the gastric wave.

II. The character of the gastric peristaltic wave.

III. The conduction of the gastric peristaltic wave.

IV. The relation of the antral contraction to the discharge of foodstuffs through the pylorus.

V. The mechanism of the pylorus; and under this a discussion of (*a*) the chemical theory of control; (*b*) the mechanical theory of control, and (*c*) the probable manner of pyloric control.

Divisions I and II form the subject of the present article; Division III will be taken up in a second article, and Divisions IV and V in a third.

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11. Wheelon, H., and Thomas, J. E.: Observations on the Motility of the Antrum and the Relation of the Pyloric Sphincter to That of the Antrum, J. Lab. & Clin. Med. 6:124 (Dec.) 1920.

ORIGIN OF THE GASTRIC WAVE

During recent years there has been a tendency to ascribe to the stomach physiologic phenomena parallel to those found in the heart. And such an attempt can be readily understood, for it would help much to clarify some of our conceptions of the physiology and surgery of the stomach were we able to show the presence of a nodal center in which the gastric waves arise and a conduction system through which they are propagated.

It has been accepted for the most part as true that the gastric waves commence in the body of the stomach. Hoffmeister and Schütz,[12] in their classical experiments, described them as commencing on the greater curvature at a level a few centimeters below the cardia. Their experiments, which will be fully detailed below, were performed on the excised stomachs of dogs. Much later, Cannon [13] found that the first waves were usually seen in the pyloric region, and that following waves began nearer to the cardia. He believed that there was no special site for the origin of the waves, but that they originated in a "tonus ring" (a contracted ring of the circular musculature) when the latter was distended by an increase of the internal pressure, and that the contraction thus started was propagated in a downward direction. He could not state, however, what the conditions were for the establishment of these "tonus rings."

But now an attempt has been made to find a gastric pacemaker that would correspond in some degree to the sino-auricular node of the heart, and it seems possible that such a center exists on the lesser curvature at the cardia, close to its junction with the esophagus. The evidence in favor of such a view is both anatomic and experimental.

While working on the nerve structures in the stomach of the rabbit, Openchowski [14] found eleven groups of ganglions on the lesser curvature at the cardia. These lay on the serosa and were in close relation to the fibers of the vagus and the sympathetic. More recently Keith,[15] while studying the nature and origin of the nodal and conducting tissue of the heart, turned his attention to the alimentary tract in the hope that he might there discover a similar structure in a less highly developed state. He found in his examinations of the stomachs of a large number of mammals that the myenteric plexus was well developed both in the

12. Hoffmeister and Schütz: Ueber die automatischen Bewegungen des Magens, Arch. f. exper. Path. u. Pharmakol. **20**:1, 1885.

13. Cannon, W. B.: The Mechanical Factors of Digestion, New York, 1911, p. 180.

14. Openchowski: Ueber die nervösen Vorrichtungen des Magens, Zentralbl. f. Physiol. **3**:1, 1889-1890.

15. Keith, Arthur: A New Theory for the Causation of Enterostasis, Lancet **2**:371, 1915.

pyloric division of the stomach and along the lesser curvature, but that it was much less abundant elsewhere in the gastric wall. Further, at the ring just distal to where the esophagus ends, there was a distinct modification of the musculature and of the plexus. Here he found a definite development of neuromuscular junctional tissue—"just such an area as might serve for a nodal center of the stomach." In the porcupine, the microscopic appearance of the tissue at this junction was very similar to that of the sino-auricular node in the heart of this animal. Keith concluded from his studies that a main nodal center for the stomach existed at the cardia and that in it the rhythmic contractions of the stomach were initiated.

The fine work of Alvarez [16] has added strength to this conception in recent years. Working first with muscle strips excised from different portions of the stomach, he showed that those excised from the lesser curvature near the cardia possessed a greater tendency to rhythmic contraction than those from any other part of the stomach, and that only the former strips could be counted on to give typical and regular contractions in every case. The rate of rhythmic contraction was most rapid at the cardia, a little slower on the lesser curvature down to the angle, and much slower in all other parts of the stomach, especially in the antrum. He further showed that with electrical stimulation of the different portions of the stomach wall the lesser curvature near the cardia displayed the shortest latent period; the rest of the lesser curvature was next, then the greater curvature, and finally the antrum. The tests for irritability yielded similar results, because stimuli that were too weak to cause a contraction in other parts of the stomach nevertheless produced that effect on the muscle from the cardia. Barbera [17] long ago reported like findings; when applying a weak faradic current to the stomach of a frog, he found that the first contraction always appeared at the cardia, entirely regardless of whether the stimulus was applied there or to the fundus or to the antrum, and that this contraction was then followed by a typical peristaltic wave.

Since, then, there is an accumulation of tissue on the lesser curvature at the cardia which closely resembles a nodal center, and since the muscle here possesses a higher degree of irritability, rhythmicity and contractility than any other portion of the gastric wall, it seems fair to assume that this part of the stomach acts as a gastric pacemaker.

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16. Alvarez, W. C.: Differences in Rhythmicity and Tone in Different Parts of the Wall of the Stomach, Am. J. Physiol. **40**:585 (June) 1916; Differences in Irritability and Latent Period in Different Parts of the Wall of the Stomach, Am. J. Physiol. **41**:320 (Sept.) 1916; The Mechanics of the Digestive Tract, New York, 1922.

17. Barbera: Ueber die Reizbarkeit des Froschmagens, Ztschr. f. Biol. **26**: 239, 1898.

But if this is true, why do not the gastric waves commence at that point? The roentgen ray apparently shows them to start, as Cannon [18] first pointed out, in the body of the stomach. But it does not necessarily follow that there actual point of origin is at the level at which they first appear on the fluoroscopic screen. For it is surely possible that a very shallow contraction of the gastric muscle may not cause a sufficiently deep indentation in the shadow cast by the barium meal to make it readily perceptible.

In the dogs examined at the laboratory, it seemed evident that the gastric waves commenced in nearly all cases at the level of the cardia. High up in the body of the stomach there usually was no indentation. But what Alvarez has very aptly called a "ripple" was readily discernible, and as this ripple spread downward it gradually grew deeper and formed the peristaltic wave visible by the fluoroscope.

That, too, seems to be the conclusion of Auer [1] and of Alvarez,[19] who is applying the galvanometer to a study of the contractions of the stomach. The electrical records show that "many of the waves which seem to begin in the lower third of the stomach have come as shallow ripples from a pacemaking region near the cardia," and that definite electrical disturbances are traveling down the upper part of the stomach in advance of the peristaltic wave, even when no movement of the muscle can be detected.

CHARACTER OF GASTRIC PERISTALSIS

Today our conceptions of the gastric peristaltic wave are for the most part dependent on the shadows seen on the fluoroscopic screen. And this picture is so readily available that the possibility of the waves being quite different under other conditions is hardly considered. But it seems quite certain that other types do occur.

As previously stated, the roentgen ray shows the wave commencing about the middle of the stomach. Shallow at the onset, it slowly deepens till it reaches the antrum, but from here on it increases markedly in depth and intensity until it reaches the pylorus. In addition, Cole [20] has described a further phenomenon, to which Alvarez,[19] after his electrical studies, also subscribes. While the waves are progressing downward, and several may be present in the stomach at one time, there

18. Cannon (Footnote 13, p. 48).

19. Alvarez, W. C.: New Light on Gastric Peristalsis, Am. J. Roentgenol. **10**:31 (Jan.) 1923; Action Currents in Stomach and Intestine, Am. J. Physiol. **58**:476, 1921-1922.

20. Cole, L. G.: The Physiology of the Pylorus, Pilleus Ventriculi and Duodenum as Observed Roentgenographically, J. A. M. A. **61**:762 (Sept. 6) 1913; Motor Phenomena of the Stomach, Pylorus and Cap Observed Roentgenographically, Am. J. Physiol. **42**:618, 1916-1917.

is a rhythmic increase and diminution of the gastric tone, resulting in a constriction and dilatation of the gastric lumen, and of the waves that are then present. Cole terms the former systole, and the latter diastole.

The first discordant voice of recent times was raised by Auer. His description is closely reminiscent of the work of the earlier physiologists. Stated very briefly, these pioneers believed that after the wave reached the antrum the musculature of the latter contracted as a whole, much like the ventricle of the heart. The newer view is that the normal peristaltic wave progresses uninterruptedly from its point of onset to the pylorus, passing over the antrum as a wave. It is very curious that all methods for the investigation of gastric motility, with the exception of the roentgen ray, yield results tending to show the existence of the former type of wave.

Beaumont,[21] who, it will be remembered, observed the stomach in man through a gastric fistula, gives his findings in the following words:

"The longitudinal muscles of the whole stomach, with the assistance of the transverse ones of the splenic and central portions, carry the contents into the pyloric extremity. The circular or transverse muscles contract progressively, from left to right. When the impulse arrives at the transverse band, this is excited to a more forcible contraction, and closing upon the alimentary matter and fluids contained in the pylorus, prevents their regurgitation. The muscles of the pyloric end, now contracting upon the contents detained there, separate and expel some portion of the chyme."

This was written in 1833.

A half century later, Hoffmeister and Schütz[12] performed their work on the stomachs of dogs. The stomach was excised after the animal was bled to death; then it was suspended in a moist chamber by means of the lesser omentum. The movements were observed through a glass window. These workers divided the gastric cycle into two parts. During the first part, the peristaltic wave begins on the greater curvature, a few centimeters from the cardia, and then passes downward, growing gradually deeper until it reaches the "sphincter antri." The second phase begins with the contraction of the "sphincter antri," which at that point practically obliterates the lumen and divides the stomach into two parts. (The term "sphincter antri" is applied to the ring of circular muscle at the beginning of the antrum.) Then follows either a general contraction of the antral musculature, including the circular, the oblique and the longitudinal, or first a shortening of the length of the antrum by one-third or one-fourth, and then a contraction of the circular muscle. They never observed peristaltic transmission of the wave in the antrum. Relaxation did not occur generally, but started in the beginning of the antrum and extended down to the pylorus. To the entire cycle they gave the name peristole. Not all the cycles were of

21. Beaumont, William: The Physiology of Digestion, Burlington, 1847.

this typical type. The most common variation was for either the first phase or the second to occur without the other. Occasionally they saw a rapid wave start at the closed pylorus and run back to the sphincter antri, terminating with a contraction of the latter. These retrograde waves were seen only in those stomachs that contained coarse food; so they concluded that some coarse particles had gotten into the antrum and, not having been pushed through the pylorus by the preceding wave, were now being forced back into the body of the stomach.

Auer,[10] utilizing the fact that the abdominal wall of the rabbit is very thin, and that if the hair is removed gastric peristalsis is easily visible through it, was able to watch the gastric peristalsis without opening the abdomen—certainly under very ideal conditions. The waves which he saw corresponded closely to those described by Hoffmeister and Schütz. Occasionally, however, a wave progressed uninterruptedly to the pylorus, just as it is seen to do on the fluoroscopic screen. Borchers,[6] who inserted a glass window into the abdominal wall of the cat and in that manner studied the behavior of the gastric waves, also found them to be similar to those described above.

After studying the dog's stomach for some time I received more and more strongly the impression that there is no such thing as a single normal type of peristaltic wave. There are at least two main types, but variations within these are quite common. Let us consider first the type corresponding to that described by Beaumont, and as outlined above.

The wave starts on the body and the greater curvature on a level with the cardia. During the early part of digestion, it is very shallow but later becomes more marked. Progressing downward it grows deeper and deeper until it finally reaches the reentrant angle at the beginning of the antrum. Sometimes the lesser curvature participates in these waves, but for the most part they are limited to the lateral and great curvatures. This might be termed the ending of the first phase.

Then the following happens: The constriction at the level of the antrum (what has been called the sphincter antri pylorici) grows rapidly deeper without moving onward, that is, it remains at the same level. While this is occurring, there is at the same time a concentric contraction of the entire antrum in which both the circular and the longitudinal fibers participate, so that the antrum diminishes both in circumference and length. These contractions finally effect a total obliteration of the antral lumen. So firm are they that at their completion the antrum looks like a hard, white, bloodless cord, and feels almost as firm as bone. Its length, too, is considerably shorter than that of the relaxed antrum, a fact that should be borne in mind in roentgen-ray observations. One can often hear fluid being squeezed through the pylorus while

the foregoing contraction is taking place. Relaxation does not occur generally throughout the antrum, but begins at the angle and spreads downward toward the pylorus so that the proximal portion of the antrum is quite relaxed when the most distal portion is just beginning to be so. This contraction of the antrum as a whole may be called the second phase.

There can be no doubt of the existence of such a type of wave. I have seen it hundreds of times when I was looking directly at the stomach. Others have seen it in the excised stomach, in the stomach in situ observed through a celluloid window, and through the thin abdominal wall of some animals. To dismiss it as a wave seen only under abnormal conditions cannot be done, for as has already been stated, Auer saw it through the intact abdominal wall of the rabbit, and Holzknecht [22] has seen it with the roentgen ray in man. The fact that the wave later referred to is the one usually seen by means of the roentgen ray can mean only that that is the type of wave that occurs under the conditions that are used to elicit it.

Both in its first and second phases this wave presents several variations. The wave coursing down over the body may not progress as far as the angle, but may gradually grow shallower and disappear when only one-half or two-thirds of the way from its goal. Or it may pass all the way down to the angle and stop there without being followed by a contraction of the antrum.

But it is the variations of the second phase that are the most interesting. To begin with this phase may occur entirely independent of the first. Thus, without any warning there may be a contraction of the antral sphincter, followed by a contraction of the antrum as a whole. At other times the wave coming down from the body may continue almost to the center of the antrum before the latter begins its systolic contraction. There are times, too, when the antrum has contracted independently of a wave from above, and then while it is relaxing a wave coursing down the body reaches it. The antrum does not respond by another contraction but continues its relaxation. The whole phenomenon reminds one very much of an extrasystole of the heart with the resultant refractory stage of the ventricle.

The second type of wave need not be so minutely described, for it is the one usually seen with the roentgen ray. Commencing at the same level as the wave described above, it passes downward, growing gradually deeper, and progresses uninterruptedly to the pylorus. While it is passing through the antrum, a contraction of the longitudinal fibers occurs at the same time, so that the length of the antrum decreases and

22. Holzknecht, quoted from Kaestle, Rieder and Rosenthal: The Complex Motor Phenomena of Various Types of Unobstructed Gastric Peristalsis, Arch. Roentgen Ray 16:242, 1911-1912.

the contraction grows more marked the nearer the wave is to the pylorus. Often there is a systolic contraction of the distal centimeter or two. I have never seen this type of wave begin independently at the angle, although I see no reason why this may not occur. The rhythm of both types is the same, there usually being from three to four waves per minute.

I tried to ascertain under what conditions the antral contraction is of the peristaltic type, and when of the systolic. It seemed logical to suppose that the presence of formed food in the stomach gave rise to the antral systole, and that the purpose of the exceedingly forcible contraction was to help reduce the solids to chyme. The presence of fluid alone in the stomach, on the other hand, necessitated only the usual peristaltic wave to express these contents into the duodenum. However, while work along this line was somewhat suggestive, it was not conclusive. At any rate, both types of waves occur in the normal stomach but the conditions which give rise to one or the other or to their variations are at present undetermined.

Retrograde peristalsis is another phenomenon that occurs. When a solid piece of food, such as an undigested piece of meat, gets into the antrum, a retrograde wave starting at the pylorus forces it back into the body. I have repeatedly produced this retrograde wave by pushing a solid piece of food from the body into the antrum. On one occasion just as I had completed the laparotomy, I noticed a retrograde wave. Palpation revealed an undigested piece of meat in the antrum.

SUMMARY

1. There is both anatomic and experimental evidence for the belief that the gastric wave originates in a nodal center on the lesser curvature at the cardia.

2. There are two main types of gastric waves: (*a*) the type usually seen with the roentgen ray, in which the wave progresses uninterruptedly from its origin to the pylorus as a peristaltic wave, and (*b*) the type in which the wave passes downward as a peristaltic wave from its origin to the reentrant angle, and this is followed by a concentric contraction of the antrum as a whole. These waves have been described in dogs, cats, rabbits and man.

3. Variations occur within these types of waves, the chief being the following: (*a*) The wave passes down over the body reaching the angle and ending there. No antral activity follows. (*b*) Antral waves may start at the angle and pass to the pylorus as independent waves, and not follow visible waves coming down from above.

4. Retrograde waves may start at the pylorus and run back over the antrum. The presence of a solid body in the antrum may initiate these.

GASTRIC MOTILITY

II. THE CONDUCTION OF THE GASTRIC PERISTALTIC WAVE *

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PROPAGATION OF THE GASTRIC PERISTALTIC WAVE

While there is no direct proof that a conduction system exists along the lesser curvature, nevertheless numerous facts tend to show that this curvature is more closely connected with the orderly propagation of gastric peristaltic waves than any other part of the stomach.

In the first place, the structural differences while not significant still are suggestive. The differences in the muscosal folds and in the glands may be passed over as not bearing especially on the present problem. Keith,[1] however, in studying the myenteric plexus found it was well developed along the lesser curvature and in the pyloric division of the stomach. In the fundus and body of the stomach, the fibers of this plexus were much less abundant. Interesting, too, is a further observation of his that stimulation of the lesser curvature near the cardia in a rabbit was followed by the contraction of the muscle at this point. This contraction passed down along the lesser curvature to the angle and then there followed a peristaltic wave which coursed down the antrum to the plyorus.

In his work Alvarez [2] found that the lesser curvature was the most rhythmic and the most irritable portion of the stomach, with the exception of that area near the cardia which has already been referred to as a possible gastric pacemaker.[3] This rhythmicity and irritability grew progressively less as the distance from the cardia increased. From these and other facts he evolved his theory of the gradients, believing that

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* From the laboratories of the Department of Surgery, Columbia University College of Physicians and Surgeons. This work is a continuation of Paper I in which the methods used were fully discussed, and in which the origin and character of gastric peristalsis were considered.

1. Keith, Arthur: A New Theory for the Causation of Enterostasis, Lancet **2**:371, 1915.

2. Alvarez, W. C.: Differences in Rhythmicity and Tone in Different Parts of the Wall of the Stomach, Am. J. Physiol. **40**:585, 1916; Differences in Irritability and Latent Period in Different Parts of the Wall of the Stomach, Am. J. Physiol. **41**:320 (Sept.) 1916.

3. Klein, Eugene: Gastric Motility, I, The Origin and Character of Gastric Peristalsis, Arch. Surg. **12**:571 (Feb.) 1926.

once the contraction had occurred near the cardia, it passed downward as a wave from the area of greatest rhythmicity to areas of progressively lesser.

Excisions of portions of the lesser curvature by the surgeon and destruction of areas by such pathologic processes as ulcer give further evidence as to the importance of this part of the stomach for normal motility. An ulcer on the lesser curvature is notoriously associated with delayed gastric motility and with vomiting. And certainly this is not always due, as Haudek [4] believed, to pylorospasm. For roentgenograms often show the pylorus widely patulous and with a barium shadow nearly as broad as that in the terminal antrum. Schlesinger [5] recently has described five such cases. In these the emptying time ranged from ten hours to three days in spite of the open pylorus. I have recently observed a patient with an ulcer on the lesser curvature near the cardia in which there was a delay of forty-eight hours in emptying the stomach, and in which the barium shadow in the pyloric ring was always 1 cm. broad. Nor can this delay be ascribed to the toxic effects of the ulcer alone. One of the operations that naturally suggested itself to the surgeon in the treatment of these ulcers was a V-shaped excision of that portion of the lesser curvature containing the ulcer. But very marked disturbances in motility persisted after this operation, and quite often they were worse than they previously had been. A gastro-enterostomy was therefore added to facilitate the emptying, and it was advised to place the stoma high up, if possible proximal to the level of the excision. But many surgeons felt that even here the functional results were poor.

In contradistinction to these findings may be mentioned those of large lesions on the body and greater curvature. With these there is little or no disturbance of gastric motility. Huge sarcomas may occur on the greater curvature. In spite of their size they are usually associated with very little delay in emptying.

Some further very interesting evidence is given by the experiments of Kaplan.[6] He was studying the effects of some surgical operations on the secretory functions of the stomach. In order to produce an hour-glass stomach, he made an incision through the anterior and posterior walls of the stomach starting on the greater curvature and passing across the body of the stomach to within 2 cm. of the lesser curvature. The anterior and posterior walls of the stomach were then sewed together

4. Haudek, quoted from Schlesinger, E.: Chronische Gastroparese als Ursache schwerster motorischer Insuffizienz bei freiem Pylorus, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **32**:30, 1920.

5. Schlesinger (Footnote 4).

6. Kaplan: Zur Lehre über den Einfluss der chirurgischen Veränderungen des Magens auf die Verdauungsprozesse, Ztschr. f. physiol. Chem. **87**:313, 1913.

on each side. This, of course, gave him an hour-glass stomach, but it was one of an entirely different character from those occurring in man. For here the initial lesion is usually on or near the lesser curvature, the latter being involved in the pathologic process. In Kaplan's work the lesser curvature was left intact, but there was a complete circular section of almost the rest of the circumference of the stomach. For that reason, his results are especially significant. We have already seen that with lesions of the lesser curvature there is a delay in motility. In Kaplan's work, on the other hand, there was no delay in emptying, much against his expectations. And in one dog in which he had left a channel of only 1 cm. in diameter along the lesser curvature, there was likewise no delay in the emptying of fluids or solids twelve days after the operation.

A curious phenomenon often occurs with these ulcers on the lesser curvature. There is a persistent spasm of the circular muscles at a point opposite the lesion. This contraction, which is in reality of the entire circular segment corresponding to the affected areas on the lesser curvature, has not, I believe, received sufficient attention. It will again be referred to later.

What is the cause for the disturbance in motility with destructive lesions of the lesser curvature? As already intimated, pylorospasm even though it may be proved guilty in some cases, cannot be the cause in all. For, as has been shown, the pylorus is often abnormally relaxed. Schlesinger [4] believes that the ulcer produces a reflex gastroparesis that affects both the pylorus and the entire stomach. But even granting that this is often true when a pathologic condition, such as an ulcer, causes the lesion on the lesser curvature, we should still have to explain the delay when a portion of the lesser curvature is excised by the surgeon, unless we wish to assume that the resulting scar has the same effect.

The work of Borchers [7] gives some idea as to what happens to the gastric peristalsis after excision of the lesser curvature. One of the operations that has recently been attempted to effect a permanent cure of gastric ulcers is a resection of the lesser curvature, or "magenstrasse." After this operation had been performed in the cat, a study of the gastric peristalsis by means of the roentgen ray showed that the gastric peristaltic waves were very superficial. No waves nearly as deep as the normal were seen. In a man who had undergone this procedure, an examination five months after the operation showed that the peristaltic waves were about one-half as deep as usual, and after four hours there was still a small barium residue. On the other hand, when the greater

7. Borchers: Ueber die Resektion der kleinen Kurvatur und deren Folgen für Magenform, Arch. f. klin. Chir. **122**:198, 1922.

curvature was excised in a cat, the waves after operation were seen to be just as deep as before and appeared to be normal. Further, Kaplan [6] of the St. Petersburg Clinic found that after resection of the fundus and a large part of the greater curvature there was no delay in the emptying of fluids or solids; on the contrary, that evacuation seemed to be more rapid.

It would seem then entirely justifiable to say, in view of these considerations, that the lesser curvature (and for present considerations that portion from the cardia to the angle is meant) is closely related to the propagation of normal gastric peristalsis, and that any severe lesion of this curvature is followed by a disturbance in motility which is due, in part at any rate, to weakening of the peristaltic wave.

CIRCULAR SPASM

We shall next consider the question of circular spasm referred to above. It is well known that an ulcer on the lesser curvature often causes a circular spasm of the entire circular segment in which it is located, so that on the roentgenogram there is an indentation opposite the niche, indicating the ulcer. Westphal [8] was able to produce a similar phenomenon experimentally. In the exposed stomach of the rabbit he irritated the mucous membrane of different portions of the stomach with the point of a pin. If done on the lesser curvature or in the antrum this caused a spasm of the entire circular segment. On the other hand, if he irritated the mucosa in the lateral walls or fundus of the stomach no such effect was produced. Occasionally only a local contraction occurred about the point of the needle. (Of course one cannot be certain with this technic which of the gastric coats were stimulated, for no doubt the point of the needle often penetrated to the submucosa or even deeper.) I was able to confirm these findings.

Summarizing, then, we may say, first, that the lesser curvature is the most irritable portion of the stomach and that it is the part most intimately connected with the orderly progress of peristalsis; and, second, that irritation of the lesser curvature may lead to a circular contraction of the entire segment. I believe these facts permit the adoption of the following working hypothesis. The impulse of the gastric peristaltic wave starts on the lesser curvature near the cardia. (This was considered in Paper I.[3]) From here it passes down through what is apparently a conduction system along the lesser curvature.[9] As the impulse reaches each successive portion of the lesser curvature there follows a contraction of that entire circular segment. In this way there is pro-

8. Westphal, K.: Untersuchungen zur Frage der nervösen Enstehung peptische Ulcera, Deutsch. Arch. f. klin. Med. **114**:327, 1914.

9. The nature of this system — whether it be muscular or nervous — is left for further study.

duced a progressive peristaltic wave passing from above downward. Under normal conditions the contraction of the upper circular segments near the cardia are quite weak; they grow progressively stronger toward the pylorus. The antrum will be considered separately below, as here somewhat different conditions obtain.

This working hypothesis permits an explanation of the disturbances in peristalsis following lesions of the lesser curvature. The effect may vary with the severity of the lesion, whether it be comparatively mild and hence irritative, or severe and destructive and hence paralytic. It emphasizes the conception that the circular muscles of the stomach are arranged in successive segments, not necessarily to be measured in centimeters, but that each portion of the lesser curvature always contracts with the same part of the greater curvature in the course of the peristaltic wave. With a marked destruction in continuity of a portion of the lesser curvature, as by a V excision, there is first produced a break in the conduction system. This apparently causes a weakening of the peristalsis distal to the point of the break and leads to delay in emptying. (Experiments bearing further on this point will be detailed below.) Second, the circular segments from which the lesser curvature has been excised are left without their most irritable portions, those that normally initiate the contractions. These "headless" segments then offer a further barrier to orderly peristalsis. For the stimulus to contract can reach them now only from the adjacent muscular segments. And though it may be possible that after a time some accommodation results, the normal progress of normal peristalsis can never again be attained.[10] Empirical recognition of these facts has led the surgeon after many dismal experience to place a gastro-enterostomy stoma proximal to the level of excision.

CONTROL OF THE ANTRUM

We shall next consider the question of the control of the antrum. It seems likely that on the lesser curvature at the commencement of the antrum, that is, the reentrant angle, a separate nodal center exists, and that in it is initiated the beginning of antral contraction. There is no direct evidence to prove this. No distinct mass of nodal tissue has been described at this point. Nevertheless, some indirect proof is in favor of this conception and it explains well the phenomena of antral contraction.

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10. Of course I am aware that other factors aid in emptying, especially in the body and in the fundus. Thus tonus waves of these parts could deliver material to the antrum, and in the "cow-horn" type of stomach tonus waves might be quite effectual agents of emptying. This question will be more fully considered at a later date.

It will be remembered that the stomach is divided into two distinct parts. On the one hand, we have the body and fundus. These act as a reservoir and permit the digestive ferments to act on the food which they hold. On the other hand, we have the antrum whose main function is motor. In a way these divisions are somewhat similar to the division of the heart into auricle and ventricle. And while the analogy does not hold altogether, we are nevertheless justified in inquiring whether, similar to the ventricle, the antrum of the stomach does not possess its own center for the initiation of its contractions. A. A. Berg [11] has long felt from clinical observations that this is true.

In the first place, the antrum exhibits a distinct tendency to independent activity. In the observation of the gastric peristalsis in dogs by the method previously detailed,[3] it was not uncommon to see this. Thus at times with no waves at all evident in the body, waves would start at the angle and pass down to the pylorus. And often this would be repeated several times. Both Hoffmeister and Schütz [12] and also Wheelon and Thomas [13] observed the same thing, and on one occasion I saw the following interesting picture: An independent antral contraction of the systolic type [3] had occurred. Meanwhile, a peristaltic wave was progressing down the body of the stomach. It reached the beginning of the antrum just as the latter was nearly but not completely relaxed. No antral contraction followed this wave. The next wave coming down from the body was followed by an antral contraction. It seemed that a phenomenon had occurred here parallel to that which takes place in the heart when the impulse from the auricle reaches the ventricle while the latter is in a refractory state due to an extra contraction.

Resection of a triangular area of the lesser curvature at the site of the reentrant angle was performed in two dogs. The opening on the lesser curvature was sewed up in a line parallel with the long axis of the stomach. One dog's stomach was observed by the method previously described [3] one month after the operation, and the other six months later. The descriptions follow:

PROTOCOLS

EXPERIMENT 1.—In Dog. 1, a triangular excision of the lesser curvature at the level of the incisura was made, Sept. 29, 1920. The wound was sewed up longitudinally. Division of both vagi at the level of the diaphragm was made. October 22, the dog was fed 250 c.c. of milk with 50 gm. of bread.

11. Berg, A. A.: Personal communication to the author.

12. Hoffmeister and Schütz: Ueber die automatischen Bewekungen des Magens, Arch. f. exper. Path. u. Pharmakol. **20**:1, 1885.

13. Wheelon, H., and Thomas, J. E.: Observations on the Motility of the Antrum and the Relation of the Pyloric Sphincter to that of the Antrum, J. Lab. & Clin. Med. **6**:124 (Dec.) 1920.

Fifteen minutes later, anesthesia was started. A transverse upper abdominal incision was made and the stomach exposed. The scar of the wound in the stomach with a few thin adhesions to it was observed, and a slight but definite indentation of the greater curvature and the anterior wall of the stomach (posterior not visible) running to the scar of the excision. The waves came down the body, starting at the level of the cardia. These were much deeper than the normal in the preantral region. The deepest contraction was at the site of this indentation. There appeared to be a pause for a fraction of a second, and then a peristaltic wave passed down the antrum, at times progressing all the way to the pylorus and at other times not. But all the antral waves were very shallow. No systolic contractions of the antrum were seen.

EXPERIMENT 2.—In Dog 2, a triangular excision of the lesser curvature at the level of the antrum was made, Dec. 1, 1920. The wound was sewed up parallel to the long axis of the stomach. The right vagus nerve was sectioned at the level of the diaphragm. June 2, 1921, the dog was given 500 c.c. of broth containing meat and small bones, and anesthesia was started thirty minutes later. A transverse upper abdominal incision was made. Waves started around the entire circumference of the stomach at the level of the cardia, and travelled downward growing deeper toward the angle. Just beyond the scar they became markedly shallower and often seemed to disappear before reaching the pylorus. At one time a few minutes after the observations were started, some systolic contractions of the antrum were seen. Palpation of the antrum showed the presence in it of some small bones. During the rest of the observation, only the weak peristaltic waves noted above were seen.

These observations then showed that after excision of the angle there was no impairment of the peristalsis proximal to this level; on the contrary, that the strength of the waves seemed somewhat increased in intensity. But there was a definite diminution in the intensity of the waves in the antrum, and, as this occurred in the motor portion of the stomach, it certainly must have interfered with motility. These experiments do not necessarily prove the presence of a nodal center in the angle. But they do show that this portion of the stomach is strongly bound up with the propagation of normal peristalsis in the antrum.

If now an entire circular segment is resected from the stomach, a so-called "sleeve resection," then a remarkable phenomenon results. The resultant scar at the suture line, of course, causes a complete break in the continuity of the intrinsic nerves and of all the muscles. Under these circumstances, the waves proximal to the suture line and distal to this line now occur independently of each other. Thus the body "beats" separately and the antrum "beats" separately. And if one may carry the analogy further, the antrum has established its idio-antral rhythm. Alvarez [2] showed that the rhythm of the antral musculature was much slower than that of the body. It is natural then to find that the rhythm of the peristalsis in the antrum under the foregoing conditions is slower than the normal peristaltic rate, since the latter is determined by the more highly rhythmic center at the cardia.

Borchers [14] studied the stomach of a cat though a glass window that he had inserted in the abdominal wall after performing a sleeve resection. From his diagram it would seem that the resection was just above the reentrant angle. He found that the waves proximal to the suture line passed down to it at the rate of four per minute. This is the normal rate. Independent waves, on the other hand, starting at the suture line ran down to the pylorus at the rate of two or three per minute.

I studied two dogs following a sleeve resection, one by the method previously described,[8] and the other by roentgen ray. In both the waves distal to the suture line occurred independently of those that were proximal.

SUMMARY

The following hypothesis would then seem justified. The gastric wave starts at a nodal center on the lesser curvature near the cardia. The impulse passes down along the lesser curvature. As it reaches each point on the lesser curvature, the entire circular ring at that level contracts and so the peristaltic wave passes down. At the reentrant angle there is a nodal center for the muscular activity of the antrum. Irritating lesions on the lesser curvature may cause a persistent contraction of the circular muscle at the level of irritation. Excision or destruction of a portion of the lesser curvature disturbs the orderly conduction and weakened peristalsis results beyond that level; the impulse reaches the muscle distal to the lesion by passing down along the lateral and greater curvatures. A segmental or sleeve resection is followed by a complete block in conduction, and the establishment of an independent rhythm beyond the level of the suture line.

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14. Borchers: Anteil des Nervus Vagi an der motorischen Innervation des Magens im Hinblick auf die operative Therapie von Magenkrankheiten; Studien zur Physiologie und Pathologie der Magen Chirurgie, Beitr. z. klin. Chir. **122**:547, 1921.

PULMONARY BLOOD PRESSURES

AN EXPERIMENTAL STUDY *

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The fact that in approximately 25 per cent. of the reported cases of lobectomy in man death is due to cardiac failure stimulated us to study the effect on the pulmonary circulation and the right heart of ligation of the pulmonary artery. It is known that in animals there is a rise in pulmonary pressure after ligation of one of the pulmonary arteries; but no one has made repeated observations to show how long the pressure remains above normal, and no one has tried to reproduce in animals a chronic lung suppuration, and then study the effect on the heart and pulmonary circulation of the various stages of the surgical operation for removal of the infected portion of the lung.

Our plan was first to assemble an apparatus and develop a technic for taking repeated tracings directly from the pulmonary artery without endangering the life of the animal. A series of six normal animals were then studied by this method, in order to show the effect of ligation of the left pulmonary artery in a normal dog. The next step in our plan was to reproduce in dogs a chronic lung suppuration. It was thought that a chronic lung abscess would probably weaken the myocardium, and that both the clinical reaction to ligation of the left pulmonary artery and the kymographic records of the pulmonary pressures would differ very markedly in these animals from those obtained after ligation in a normal animal.

We were never able to develop our plan of investigation beyond the first stage because we found it impossible to produce a chronic lung abscess in a dog. The fact that the dog's lung is so strikingly resistant to all attempts to produce a chronic infection probably explains why it has never been possible to reproduce in these animals the bronchiectatic cavities so common in man. We began cautiously at first by opening the chest and injecting into the center of a lobe of lung 1 c.c. of semifluid agar containing virulent pneumococci. But as nothing happened to these animals we began injecting, under fluoroscopic guidance, larger and larger quantities of agar containing the most virulent organisms we could obtain, such as streptococcus, staphylococcus, the sputums from clinical cases of lung abscess, and the organisms recovered from the nasal discharge and from the lungs of dogs dying of distemper. All of these failed to produce a chronic lung suppuration, even when injected into

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the lung in enormous quantities and at frequent intervals. The preliminary injection of boiling water through the chest wall into the center of a lobe to produce necrosis, and the occlusion of the bronchus with foreign bodies failed to cause a chronic infection in the lung even after organisms were introduced as described above.

So, after failing to produce a chronic lung suppuration in any one of our fifty dogs, we were forced to abandon our original plan. This article, therefore, describes only the apparatus and the operative method that will permit a series of blood pressure tracings from the pulmonary artery without infection or injury to the heart. The immediate changes that occur in pulmonary blood pressure after ligation of the left pulmonary artery have been reported by Kuno,[1] Underhill[2] and Haggart and Walker;[3] they did not, however, make observations on the pulmonary blood pressure extending over days or weeks. It seems worth while, therefore, to describe a method by which this may be done, and to report the changes in pulmonary blood pressure found in normal dogs, one, two and three weeks after ligation of the left pulmonary artery.

METHOD

Six dogs of approximately the same size were used in these experiments. The left pulmonary artery was ligated and subsequent tracings of the pressure in the main pulmonary artery were made until the postligation pressures had returned to preligation levels.

Each animal received one-fourth grain (0.01 gm.) of morphin immediately before operation. Intratracheal ether anesthesia with intermittent pressure was used in each case. The animals were maintained at a depth of anesthesia just sufficient to abolish the corneal reflex, and the movements of the lung were made to follow those of the chest wall. All operative procedures were carried out aseptically. With the animal lying on the right side, an incision was made between the third and fourth ribs; this afforded a good exposure of the left lung, the great vessels and the pericardium. The left pulmonary artery was then exposed and a medium silk ligature passed around it, but not tightened. The pericardium was next opened and a traction suture placed in the anterior wall of the right ventricle near the attachment of the semilunar valves. With the aid of this suture a medium sized metal cannula was passed through the wall of the ventricle, past the semilunar valves, and into the

1. Kuno, Y.: Contributions to the Physiology of the Pulmonary Circulation, J. Physiol. **50**:140, 1915-1916.

2. Underhill, S. W. F.: An Investigation into the Circulation Through the Lungs, Brit. M. J. **2**:779 (Nov. 12) 1921.

3. Haggart, G. E., and Walker, A. M.: The Physiology of Pulmonary Embolism as Disclosed by Quantitative Occlusion of the Pulmonary Artery, Arch. Surg. **6**:764 (May) 1923.

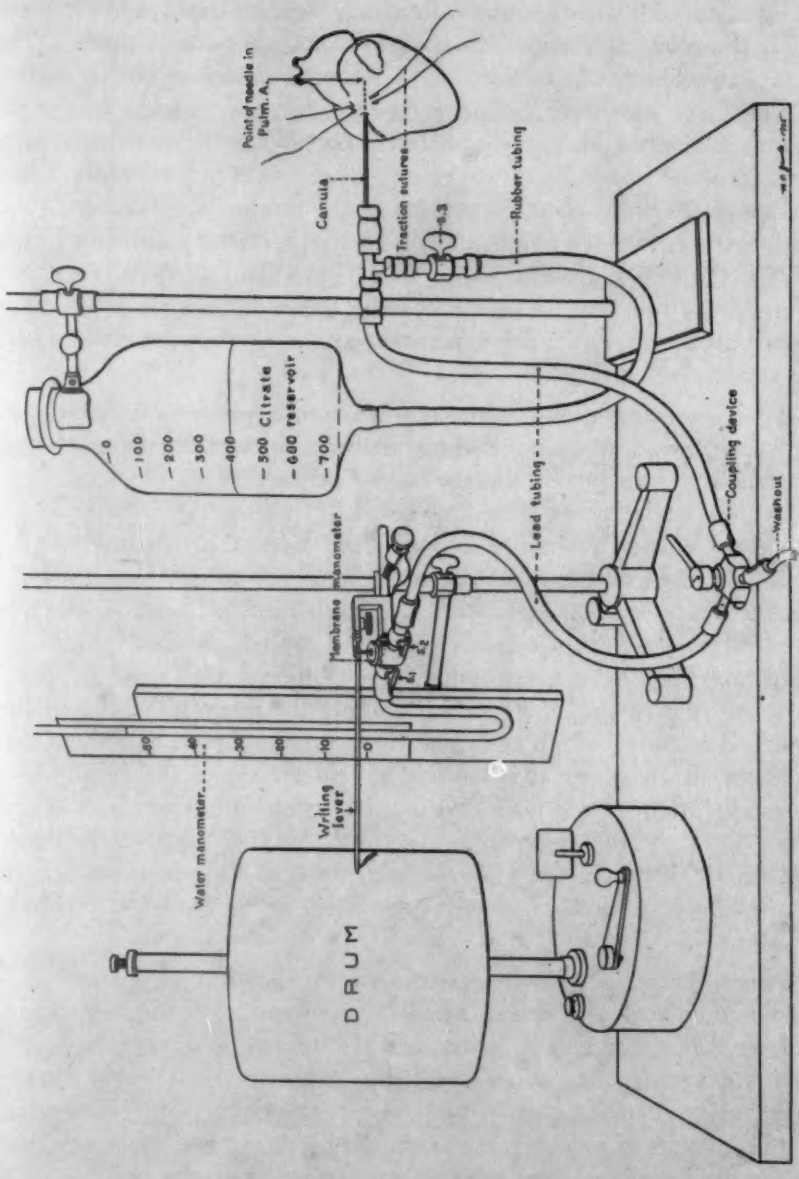

Fig. 1.—Apparatus for recording blood pressure in the pulmonary artery.

main trunk of the pulmonary artery.[4] The ligature previously laid about the left pulmonary artery was now tightened. The changes of pressure occurring within the pulmonary artery were conducted by means of lead tubing filled with citrate solution to a very delicate membrane tambour, which recorded all changes on a slowly moving smoked drum. The drum was calibrated in millimeters of water as described below. After the blood pressure changes had been recorded, the cannula was withdrawn and the traction sutures about the opening in the ventricular wall were tightened if necessary to prevent bleeding. The pericardium was then repaired with continuous sutures of fine black silk. The ribs above and below were drawn tightly together with pericostal sutures of heavy silk, and the muscle and skin layers were closed with interrupted sutures of fine black silk. In the last four dogs following ligation of the pulmonary artery, the entire left lung was removed. The reason for doing this will be discussed below.

The apparatus used to record the blood pressure is shown in Figure 1. The zero mark on the water manometer, the membrane on the recording manometer, and the dog's heart are all on the same level. A coupling device permits the cannula, lead tube, citrate reservoir and connecting rubber tubing to be sterilized with the instruments and quickly attached to the manometer after the operating table has been draped. To record pressures, stopcock S_1 is closed, S_2 is open, and S_3 is closed. The system then consists of an open cannula, connecting through a lead tube filled by a 3 per cent. citrate solution with a tambour and a slowly moving smoked drum. To calibrate the records the end of the cannula is occluded with a cork and the stopcocks S_1 and S_3 are opened. When the citrate reservoir is lowered so that the top of the fluid in it is at the level of the dog's heart, the writing lever will record a zero line on the drum. If the reservoir is now raised until the manometer reads fifty, the writing lever will record a level equal to 50 mm. of water. In this way the drum is calibrated for pressures ranging from 0 to 500 mm. of water.

Normal pulmonary blood pressures vary widely in the dog (comparison should be made of Figures 2 and 7), the normal systolic levels varying from 250 to 375 mm. of water, and the normal pulse pressures from 100 to 200 mm. The cause for these wide variations could not be determined. All the animals used were approximately the same size, and the amounts of morphin, the depth of anesthesia, and the degree and rate of inflation of the lungs were all standardized so far as possible. No

4. Schafer, E. S.: A Convenient Method of Recording Pulmonary Blood Pressure, Quart. J. Exper. Physiol. **12**:133, 1920. Swift, W. E.; Haggart, G. E., and Drinker, C. K.: A New Method for Measuring the Pressure in the Pulmonary Artery, J. Exper. Med. **36**:329 (Sept.) 1922.

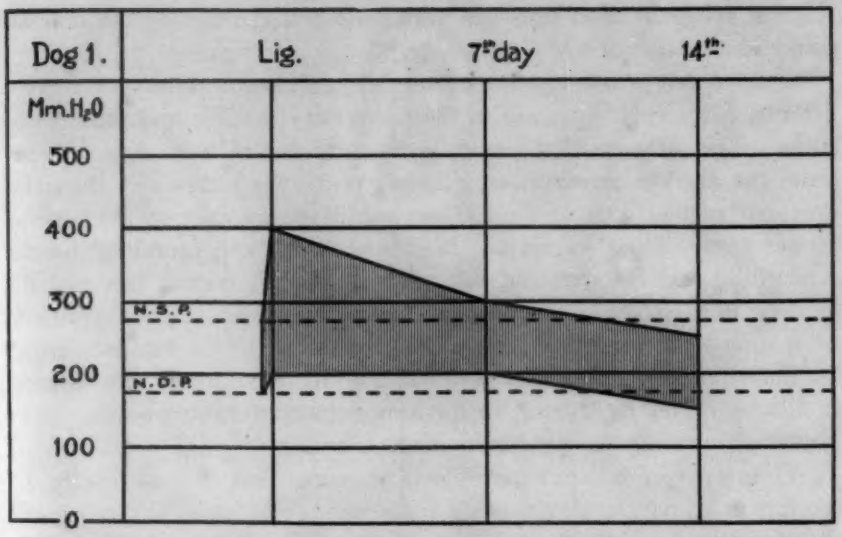

Fig. 2.—Composite of several blood pressure tracings from the pulmonary artery just distal to the pulmonary valves. The rapid rise of both systolic and diastolic blood pressures immediately after ligation of the entire left pulmonary artery, and the gradual return to the normal level, should be noted.

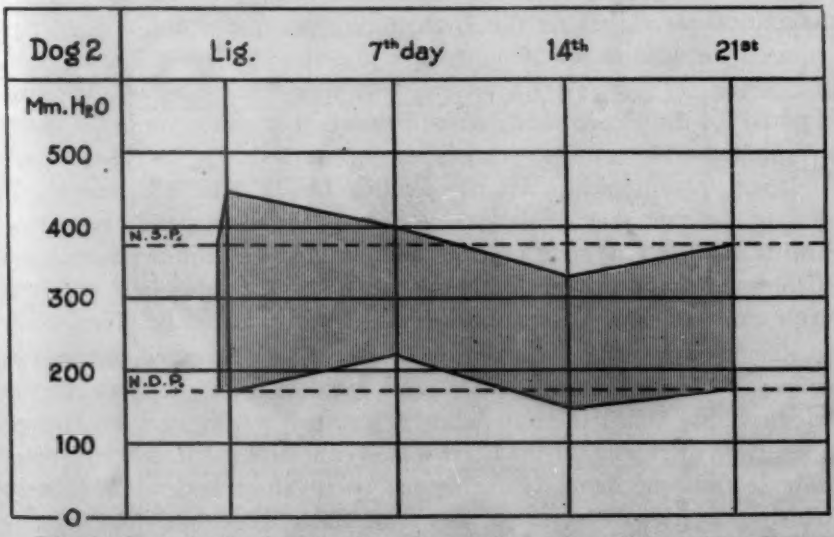

Fig. 3.—Record of animal having a vegetative endocarditis and insufficiency of the pulmonary valve. The high initial systolic level, the pulse pressure of 200 mm., the small rise of systolic pressure, and the absence of any immediate rise in diastolic pressure after ligation of the left pulmonary artery should be noted. The systolic pressure did not return to the normal level until the tenth day after ligation.

relation between blood pressure variations and the age of the animals could be established.

Immediately after ligation of the left pulmonary artery there is a definite and a rapid increase in the pulmonary systolic and pulse pressures. The increase in the systolic pressure varies from 30 to 50 per cent., the average increase being 35 per cent.; the increase in the pulse pressure varies from 35 to 100 per cent., the average increase being 50 per cent. These values are in accord with those found by Kuno,[1] Underhill [2] and Haggart and Walker.[3] It is a significant fact that the increase in systolic pressure is in no instance proportional to the amount of lung substance removed from the circulation. This suggests either an immediate and considerable dilatation of the already functioning capillaries of the right lung, or the almost instantaneous opening up of previously existing but nonfunctioning channels.

The elevation in pulmonary blood pressures that follows ligation of the left pulmonary artery persists for a number of days, but eventually the pressure returns to normal. In one animal the pressure had returned to normal on the seventh day after ligation; in four animals it did not reach the normal level until the fourteenth day, and in one animal not until the twenty-first day. This return of pressure levels to normal probably does not depend on a compensatory hypertrophy of the remaining lung tissue, for in several instances the blood pressure had reached the normal level before the hypertrophy was apparent. The time required for adjustment of pulmonary pressure changes following ligation of the left pulmonary artery in dogs approximates closely the time required for the physicochemical adjustments that take place in the blood stream following similar procedures, as worked out by Heuer and Andrus.[5] The atypical chart representing Dog 2 deserves attention, in view of the fact that necropsy revealed an advanced vegetative endocarditis limited to the right ventricle and producing a definite insufficiency of the pulmonary valves. No explanation for the subnormal pressure levels observed on the fourteenth day after ligation can be given.

Roentgenograms were taken or the heart was observed fluoroscopically and changes in rate and rhythm were noted throughout all the experiments. When the left pulmonary artery was ligated, no change in size, rate or rhythm of the heart was ever apparent. Roentgenograms made at frequent intervals during the twenty-four hours immediately following ligation never reveal any appreciable dilatation. Roentgeno-

5. Heuer, G. J., and Andrus, W. D. W.: The Alveolar and Blood Gas Changes Following Pneumectomy, Bull. Johns Hopkins Hosp. **33**:130 (April) 1922. Andrus, W. D. W.: Observations on the Total Lung Volume and Blood Flow Following Pneumectomy, ibid. **34**:119 (April) 1923; Observations on the Cardiorespiratory Physiology Following the Collapse of One Lung by Bronchial Ligation, Arch. Surg. **10**:506 (Jan.) 1925.

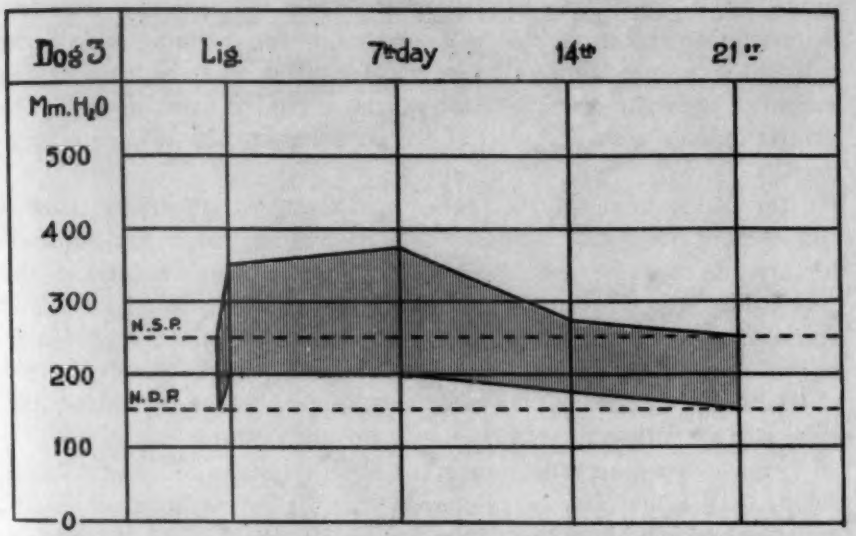

Fig. 4.—Record showing the pressure changes that occur in the pulmonary circulation after ligation of the left pulmonary artery in a normal dog. There is a rise in systolic and diastolic pressures immediately following the ligation. The pressures do not begin to fall until after the seventh day and do not reach the normal level until the twenty-first day.

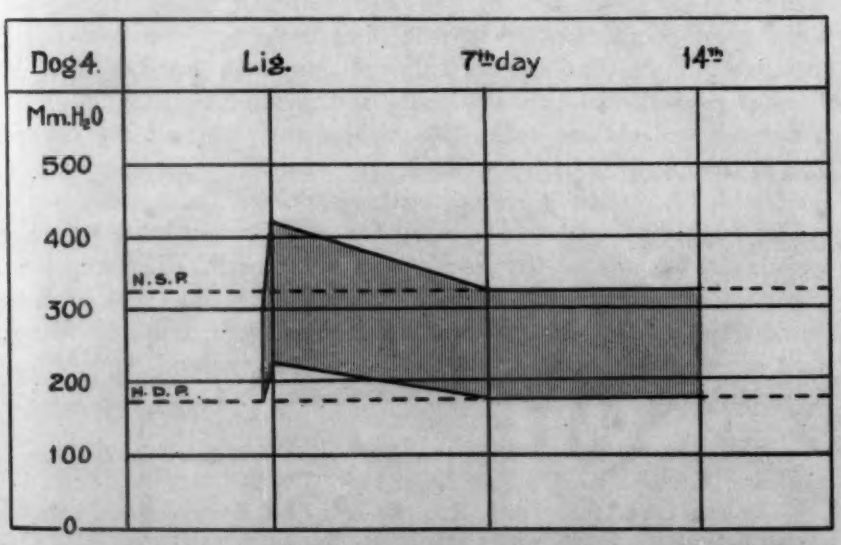

Fig. 5.—Record of animal in which the pulmonary blood pressure had returned to the normal level on the seventh day after ligation of the left pulmonary artery; when compared with Figure 4, this suggests that there is a marked variation in normal animals.

grams taken from three to five months after the operation show no demonstrable hypertrophy of the heart. Careful anatomic dissections, cutting as close to the septum as possible, show that the ratio of the weight of the right ventricle to the weight of the left ventricle is always greater in dogs after occlusion of the pulmonary artery than in normal dogs.

The pericardium may be opened and resutured repeatedly without endangering the life of the animal. Pericardial effusion was observed in only one dog after a subsequent operation. Adhesions between the pericardium and the heart were absent at the second operation in four animals; at the third operation in three animals, and at the fourth operation in one animal. The adhesions were located most frequently at the site of the needle puncture; next, along the line of suture; and only once were they present elsewhere than at a suture line.

Some of our observations suggest that an interference with the blood supply of the lung may be responsible for the development of pleural effusions and adhesions. In the first two experiments, the left lung was not removed after ligation of the artery. These animals recovered from the operation without shock, but on the third or fourth day they refused food and were very drowsy and inactive. The chest was reopened in these two animals on the seventh day after ligation, and from 5 to 10 c.c. of sterile, rather heavy, serosanguineous fluid was found in the pleural cavity; the lung was dark red, engorged with blood and friable, and fibrinous adhesions extended from the lung to the line of incision in the chest wall. At a third operation on the fourteenth day, the fluid had disappeared and the lung was paler and smaller in size, but fresh fibrinous adhesions had formed over the greater part of the visceral pleura, binding the lobes to each other and to the pericardium and the chest wall. At necropsy several months later, the pleura was dry and the lung greatly shrunken and of rubbery consistency, but there were organized adhesions between the lobes and the neighboring structures. The microscopic changes observed, from the early stages of vascular engorgement to the replacement of lung tissue with connective tissue, were essentially those described by Küttner,[6] Bruns and Sauerbruch,[7] Kawamura[8] and Schlaepfer.[9] In Experiments 3, 4, 5 and 6, the left

6. Küttner: Beitrag zur Kenntniss der Kreislaufsverhaltnisse der Saugethierlunge, Virchows Arch. f. path. Anat. **73**:476, 1878.

7. Bruns, O., and Sauerbruch, F.: Die künstliche Erzeugung von Lungenschrumpfung durch Unterbindung von Aesten der Pulmonalarterie, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **23**:343, 1911.

8. Kawamura, K.: Ueber die künstliche Erzeugung von Lungenschrumpfung durch Unterbindung der Pulmonalarterienäste und den Einfluss derselben auf die Lungentuberkulose, Deutsch. Ztschr. f. Chir. **125**:373, 1913.

9. Schlaepfer, K.: Ligation of the Pulmonary Artery of One Lung With and Without Resection of the Phrenic Nerve, Arch. Surg. **9**:25 (July) 1924.

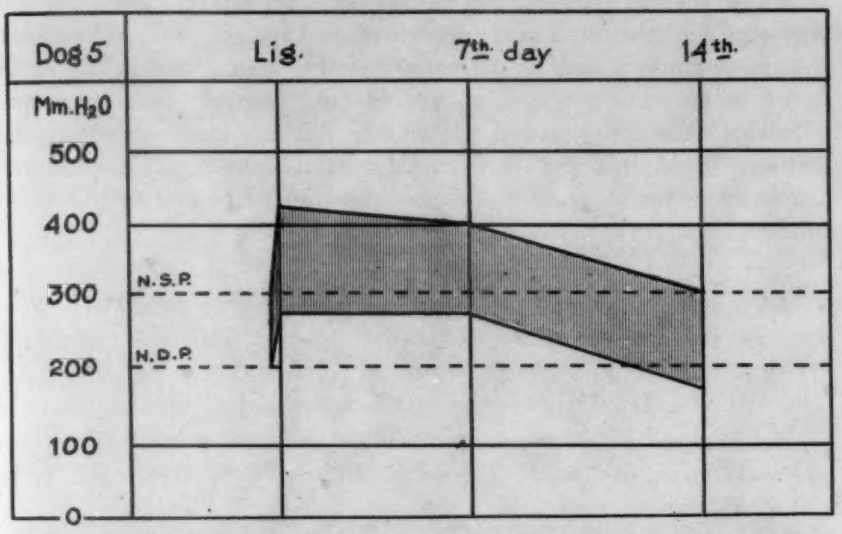

Fig. 6.—Record showing that after the rapid rise of 125 mm. of water following ligation of the pulmonary artery the systolic pressure falls only 25 mm. during the first seven days, and the normal level is not reached until the fourteenth day.

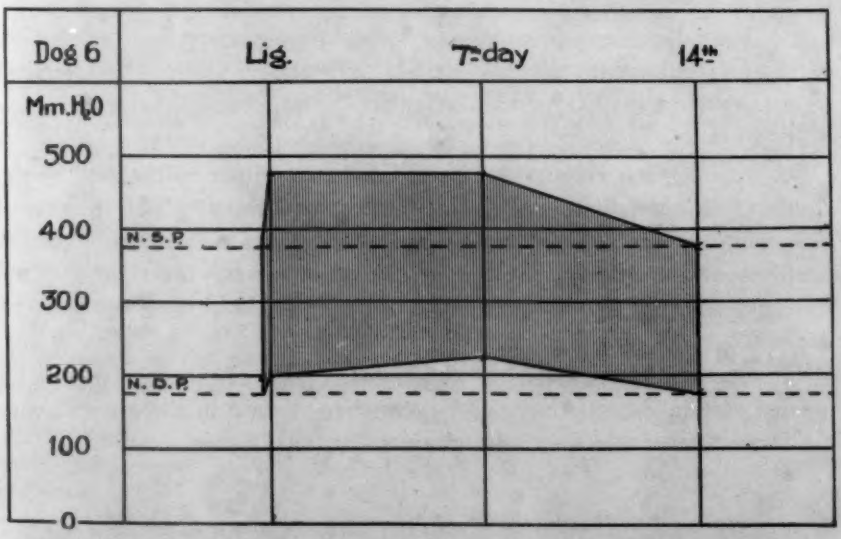

Fig. 7.—High systolic and pulse pressures; after ligation of the left pulmonary artery the pulse pressure increased 75 mm. of water, and this great pulse pressure persisted for seven days.

lung was removed after ligation of the pulmonary artery. These animals recovered without shock and never developed the symptoms of toxemia seen in Animals 1 and 2. Free fluid in the pleural cavity was never found at subsequent operation, and in only one dog were there any adhesions at necropsy several months later. These observations suggest that lung tissue deprived of its normal arterial blood supply and allowed to remain within the chest favors the formation of pleural effusions and adhesions.

SUMMARY

1. The described method for obtaining tracings of pulmonary blood pressure through an open pericardium directly from the pulmonary artery of dogs permits of repeated blood pressure determinations on the same animal without danger of infection or hemorrhage within the chest.

2. The normal pulmonary systolic blood pressure in dogs varies from 250 to 375 mm. of water; the normal pulmonary pulse pressure, from 100 to 200 mm. of water.

3. The increase in the systolic pressure in the main pulmonary artery of a dog after ligation of the left pulmonary artery varies from 30 to 50 per cent.; the pulse pressure increase varies from 35 to 100 per cent.

4. This increase in both systolic and pulse pressures persists for a number of days, but eventually returns to normal. The time required is between seven and twenty-one days, fourteen days being the average time.

5. The adjustment of pulmonary blood pressure levels after ligation of the left pulmonary artery parallels very closely the physicochemical adjustment in the blood stream after similar procedures, as reported by other workers.

6. The dog's heart shows very little change either in the rate or the rhythm following ligation of the left pulmonary artery. With the exception of a somewhat abnormally thickened right ventricular wall at necropsy and a difference in the weight ratio between the right and the left ventricle, we found no evidence of a compensatory hypertrophy of the heart.

7. Observations apparently indicate that lung tissue deprived of its normal arterial blood supply and allowed to remain in the chest favors the formation of effusions and adhesions.

REPORT OF SUBCOMMITTEE ON SURGICAL CONVALESCENCE OF THE PUBLIC HEALTH COMMITTEE OF THE NEW YORK ACADEMY OF MEDICINE

I. DEFINITION OF A CONVALESCENT HOME

After considerable discussion the committee felt that a convalescent home should be considered as a place where patients who are recovering from an acute illness may spend the time necessary for them to return to economic efficiency. The time required naturally will depend on the state of the patient's health and the nature of his or her preceeding illness. This cannot be measured in months, weeks or days, and the time element should be left elastic. The only criterion for admission to a convalescent home should be that any individual patient will in time completely regain his or her strength and not become a permanent burden or inmate of such a home.

II. NEED OF INSTITUTIONAL CONVALESCENCE

During the convalescent period it is felt that for the majority of ward patients, institutions for their care are preferable to their homes, as the latter do not as a rule provide an environment conducive to rapid recovery.

III. NEED OF CONTINUITY OF TREATMENT CONTROL

In order that the interests of the individual patients be protected and the best surgical results obtained, there should be a continuity of treatment control. The hospital which is directly responsible for the treatment while the patient is under its roof is morally responsible for the continuation of it when the patient is transferred by the hospital to a convalescent home.

As most of the convalescent institutions serving New York City are independent organizations, having no organic connection with the hospitals with services for acute cases, the question of liaison between them is most difficult of solution.

IV. RELATION BETWEEN HOSPITAL AND CONVALESCENT HOME

The committee considered this problem at great length and the following two plans were proposed and discussed.

1. The hospitals should appoint junior members of their surgical staffs to serve as liaison officers between the institutions. The duty of such officers would be to visit the patients transferred from the hospital at regular intervals in one or several convalescent homes. Their relationship to the convalescent home would be that of a visiting physician. Such officers should be paid by the hospitals. Although this plan would certainly guarantee a continuity of treatment, the committee felt that it was open to a number of serious objections.

(*a*) It is doubtful whether the hospitals in general would be willing to pay for the services of a liaison officer.

(*b*) As the patients from one hospital would be distributed among several convalescent homes widely scattered, the time required to visit them would be so great that a liaison officer would have time for little else.

(*c*) As each convalescent home would receive patients from many hospitals there would be grave danger of confusion with many surgeons directing the care of its patients.

2. A close connection should be established between certain convalescent homes and certain individual hospitals by which all patients from that hospital would be cared for by a certain individual convalescent home, and a liaison officer should then be appointed to direct their care. The hospital would then require its junior attendants to rotate in the capacity.

(*a*) Although this was felt to be an ideal arrangement for some of the larger hospitals, it failed to provide for the patients in the smaller hospitals and the city institutions.

(*b*) It was doubtful whether any convalescent home would be willing to confine its activities to the care of patients from any one hospital. Such an arrangement would have to be entered into between the managers of the individual hospital and the convalescent home. The committee feel that it would be a great advantage if this were done in certain instances.

3. Each hospital should designate one or several of its junior attendants to serve as liaison officer, who would respond to calls by the staff of the convalescent home for consultation on the cases that did not appear to be making satisfactory progress.

(*a*) It would place the responsibility of the care of the patients on the staff of the convalescent home and so develop a healthy professional interest in the individual case.

(*b*) It would serve as a check on the professional staffs of the hospitals not to abuse the facilities of the convalescent homes by unloading cases on them which were unsuited to convalescent care and required constant visits of the liaison officer.

(*c*) It would serve as a follow-up on any doubtful result in patients discharged from the hospital.

(*d*) It would furnish to the professional staff in the hospital criteria as to the efficiency of the care given by each convalescent home.

Your subcommittee favored the last plan as best covering the problem for the majority of hospitals.

V. SPECIALIZATION IN CONVALESCENT CARE AND ITS REQUIREMENTS

The convalescent homes should be grouped somewhat broadly as to the character of cases which they would be fitted to care for. There are certain conditions which by the nature of the ailment require longer convalescence than the average run of cases, or special equipment not required outside of that group.

The types of conditions that require specialization in separate convalescent homes are as follows:

1. Injuries to the extremities, such as fractures, dislocation, sprains and joint injuries, osteomyelitis, deformities following infections, burns, tendon injuries, tuberculous glands, tuberculous peritonitis and fistula.

This group would require sun parlors, sun porches, roentgen-ray apparatus, Alpine lamp, massage, and a certain amount of mechanotherapy.

2. Goiter cases, stomach cases, intestinal resections, debilitated cases requiring high caloric diet, etc.

This group should have available proper rest rooms and rest hours controlled by the attendant in charge. There should also be facilities for a certain amount of specialized diets.

3. Abdominal cases following laparotomy and gynecologic cases. This group would require facilities for simple dressings, enemas and douches, colon irrigations and trained attendants to administer such simple treatment.

4. Patients who have syphilis as an accompanying condition or as the primary cause of their illness should be sent to such convalescent homes as provide the proper facilities for administering antisyphilitic treatment.

5. The majority of orthopedic cases are best treated in the convalescent homes directly affiliated with the central hospital, as is done for instance at the New York Orthopedic Hospital or St. Giles Hospital. The committee feel that it would be most advantageous if some of the convalescent homes would specialize in this important branch of the work.

6. Pulmonary tuberculosis cases should be taken care of in special sanatoriums devoted to that purpose.

In general we feel that every convalescent home should provide facilities for occupational therapy and have a form of physiotherapy, and that a routine be established by which every patient would be afforded opportunity for rest and quiet for certain periods of the twenty-four hours other than at night.

VI. RESIDENT STAFF

In addition to the foregoing specific considerations, this committee feel that every convalescent home taking surgical or postoperative cases requiring dressings and treatment should have a competent resident surgeon and at least one trained nurse and the necessary number of trained attendants. This would depend on the size of the institution and the type of cases cared for.

VII. CENTRAL INFORMATION BUREAU

The committee also recommended the establishment in the city of some kind of central bureau where a daily census would be kept of available space in the various homes, so that the hospitals might deal through this bureau in finding accommodations for the cases suitable for convalescent care. This would simplify the task of placing these patients and could serve as a means of utilizing all the convalescent homes to the best advantage and prevent overcrowding of any particular convalescent home to the neglect of the others.

Respectfully submitted.

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TWENTY-EIGHTH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY

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(Continued from Page 168)

FRACTURES, DISLOCATIONS AND AMPUTATIONS

How Can Fracture Treatment be Improved?—Sir Robert Jones,[40] in delivering the Lady Jones Lecture before the University of Liverpool, selected as text the present unsatisfactory state of fracture treatment and severely arraigned the authorities of the large teaching hospitals for their lack of interest in fractures and their failure to profit from the lessons of the war. Success in the treatment of the war fractures was obtained only after several years of failure and was brought about by the segregation of these cases in the hands of a corps of experts who supervised the treatment from start to finish. Simplification of apparatus, standardization of methods and team play were important factors, along with the expert supervision. Contrasting this with the present methods of handling fractures in the hospitals he states that most of the surgeons into whose hands the cases fall are often interested chiefly in abdominal surgery, that the treatment is passed over to inexperienced house surgeons, and that pressure is continually being made to get the patients out of the hospital to make room for other types of cases.

Jones considers the effects of this general attitude on fracture teaching as extremely deplorable. With rare exceptions the surgeons neglect to teach because few of them are sufficiently interested or informed to do so. The medical student is brought up in an atmosphere in which the treatment of fractures occupies a subsidiary position and it is only after he has qualified and is called on to assume charge of a case that he realizes how little he knows of the subject. This accounts for the bad results so frequently encountered.

To remedy this state of affairs Jones proposes the organization of special fracture clinics in the teaching hospitals. Cases of fracture should be segregated as much as possible and should be under the complete control of this special surgical unit. It should also have

40. Jones, Robert: Brit. M. J. **1**:909 (May 16) 1925; abstr., J. A. M. A. **84**:1962 (June 20) 1925.

charge of the special fracture clinic in the outpatient department. The director of the unit should be an experienced surgeon, with a special interest in and knowledge of fractures, one with broad vision and mature judgment. The chief of the orthopedic department should act as consultant or fill a more important rôle. The fracture clinic should be under the charge of a fracture team made up, first, of one or more specially interested surgeons; second, of a senior assistant whose tenure of office should be sufficiently long to render him expert and qualify him for section teaching, and, third, of the physiotherapist. The house surgeons, dressers and clinical assistants would attend the clinic as a part of their regular duties. A specially trained nurse to assume charge of the fracture ward would also be a necessary member of the fracture team.

In England Jones' article set fire to tinder that evidently had been long smoldering. This is shown by the lively and lengthy debate on the treatment of fractures which occupied the joint session of the surgical and orthopedic sections at the annual meeting of the British Medical Association at Bath.[41]

Proceedings of Sections, British Medical Association.—Gask,[42] who opened the discussion with an address conspicuous for its moderation and fairness, took strong exception to the statement that most surgeons in general hospitals should be classed as abdominal surgeons. Gask is himself an eminent surgeon and may be presumed to have appeared as the spokesman for the general surgeons. The admission coming from such a source that something is lacking in the treatment and teaching of fractures and that there is a considerable amount of unnecessary crippling, and therefore that all is not well and that reforms are necessary at once, reduced the questions at issue to one of how to reorganize in order to remedy these defects. His chief argument against a special fracture service was that it would result in specialization, whereas the whole need was for development in the opposite direction. Yet a subsequent speaker called attention to the fact that the section on fractures in Gask and Wilson's Surgery was written by an orthopedic specialist.

Speakers of ability followed one another, including Sir Robert Jones, H. Wade, R. B. Osgood (United States), H. A. Fairbank, A. W. Sheen, and many others. The pros and cons were all stated. All admitted the need of improvement, but the inadequate number of hospital beds and the fear of specialization were the specters which continually haunted the thoughts of most of the surgical speakers. Osgood described the organization of the fracture service at the Massachusetts

41. Jones, Robert: Brit. M. J. 2:319 (Aug. 22) 1925.
42. Gask, G. E.: Brit. M. J. 2:317 (Aug. 22) 1925.

General Hospital, in which both general surgeons and orthopedic surgeons participate. Far from increasing specialism he said, this reform "had added a reagent which had dissolved some of the precipitate thrown down by the specialties and made it again a part of the general solution."

[ED. NOTE.—We have reported the foregoing article and discussion at considerable length because both seem of great importance. Jones has called attention to a state of affairs that requires reform, and it exists not only in England but also in this country. Happily here we have already made a little progress in the right direction. Fracture services have been organized in several of our leading hospitals and are functioning with great success. This is only a small beginning of what is needed but additional progress may be expected to follow from the efforts that the American College of Surgeons through its fracture committee is making with the smaller hospitals. Before reform can be accomplished it is first necessary to see the need for reform, and, in the past, the chief difficulty has been an unwillingness to look the situation in the face. This discussion has gone far to clarify the atmosphere in England, and we believe that it will also aid progress in this country.]

The Operative Treatment of Fractures.—Rixford [43] contends that spiral fractures constitute so large a group and are so uniformly characteristic in form that they deserve to be treated as a separate class. An understanding of the mechanism by which they are produced allows one to comprehend their clinical behavior and also makes evident the basic principles of proper treatment.

Arguing for routine operative treatment of spiral fractures he states that the objections to nonoperative methods are, first, that these fractures cannot be accurately reduced; second, that a little displacement, especially in a rotary sense, leads to a considerable deformity in the clinical sense; third, that an external rotary deformity in the bones of the leg leads to fallen arches, and, fourth, that union is frequently delayed because of the entrance of fibrous bands between the fragments.

Lane,[44] reviewing the changes that have taken place in the treatment of fractures during the last thirty years, states that in spite of the progress that has been made, no branch of surgery is in so unsatisfactory a condition. He attributes most of the poor results to the fact that a majority of the surgeons lack the opportunity of becoming familiar with a large variety of fractures, and this leaves them without the necessary skill. Few surgeons appear to have sufficient mechanical

43. Rixford, E.: Ann. Surg. **81**:368 (Jan.) 1925.
44. Lane, W. A.: M. J. & Rec. **121**:261 (March 4) 1925.

knowledge or experience to deal effectually with fractures by operative procedures. The wide use of unsuitable plates and screws to secure alinement, and the lack of proper aseptic precautions has resulted in many sad failures. It is imperative that fracture operations and bone grafting procedures be performed only by skilful surgeons.

[ED. NOTE.—When Lane, the inventor of bone plating, sounds a conservative note in respect to the operative treatment of fractures, it surely deserves to be underlined. However, it is not so much the method of treatment he is criticizing as the promiscuous way in which it is being done.]

Removal of Screws and Plates After Insertion in Bone.—The removal of foreign bodies used in the fixation of fractures has been much discussed and a great difference of opinion has been expressed in regard to the necessity of such procedures. Ashhurst,[45] attempting to clarify this situation, records his experience in a group of 101 cases. The metal fixation has been removed in only nineteen instances. In the other eighty-two cases it has remained in for varying periods up to fifteen years. In four cases it was removed for the relief of pain, but in none of the patients was the pain materially altered, showing that it was due rather to the persistence of a slight degree of deformity. In six cases the removal was necessitated by the presence of infection. In eight cases the foreign body was removed during the course of some secondary operation. In one case a screw worked loose beneath the skin and was removed three months after operation. Ashhurst concludes that if one considers only the six cases of infection, and the one of loose screw, it does not seem that metal fixation when properly employed is to be condemned, nor, as many surgeons contend, that "a majority of plates have to be removed," nor that all screws become loose.

Relation of the Thyroid to the Healing of Fractures.—Goldner [46] has made an investigation of the activity of the thyroid during the healing of fractures, and finds definite evidence of hyperfunction at that time. This is shown by an hyperplasia of the interfollicular tissue which becomes evident as soon as the provisional callus begins to form. He concludes that these changes in the gland are signs indicating that the thyroid plays a part in the fixation of the mineral salts in the bone.

Spontaneous Fracture of the Ossified First Costal Cartilage.—Amenille [47] reports the case of a woman, aged 68, who sustained a

45. Ashhurst, A. P. C.: Ann. Surg. **81**:528 (Feb.) 1925.

46. Goldner, J.: Compt. rend. Soc. de biol. **92**:725 (March 13) 1925.

47. Amenille, M. P.: Bull. et mém. Soc. méd. d. hôp. de Paris, Jan. 30, 1925, p. 147.

spontaneous fracture of the ossified cartilage of the first rib. The injury occurred while she was asleep and she was awakened by the pain. There were local tenderness and swelling, and the lesion was demonstrated roentgenologically. The symptoms disappeared after fifteen days. Amenille states that he has found fractures of ossified chondral cartilages in dissecting room subjects as often as one in three. They are always in adults, usually beyond the age of 50, and rarely involve other than the first costal cartilage. So far as he has been able to ascertain they rarely give rise to symptoms, this being the first case reported. Discussing the mechanism of injury, the author says that of all the costal cartilages the first is most subject to efforts of flexion and torsion. Investigation has shown that it is also the first to undergo senile evolution ending in ossification, this rendering it more brittle and liable to fracture. These two facts appear sufficient to account for the frequency of these fractures.

End-Result Study of Fractures of the Head and Neck of the Radius.—Sever [48] has studied a series of forty-seven cases of fracture of the head and neck of the radius, and has been able to ascertain the end-results in twenty-eight. From this study he concludes that in fractures of the head itself with only a vertical or horizontal crack, good results are generally to be expected from fixation in the right angle position for a period of two weeks, followed by baking and massage. The common impacted fractures of the head and neck also give good results without operation. Even with considerable displacement of the radial head on the shaft, good function has eventually resulted in this series. In cases of fracture dislocation with complete separation of the head and neck the author advises excision. He advocates not only the removal of the head but splitting the orbicular ligament and excising the neck nearly to the bicipital tuberosity. The risk of the radius riding forward from the pull of the biceps, he states, is not of sufficient importance to weigh against the gain in ability to supinate and pronate. After incomplete removal, when the neck has been left, rotation of the forearm is often as limited as before operation.

Separation of the Upper Epiphysis of the Radius.—Montgomery [49] reports a case of separation of the upper epiphysis of the radius in a girl of 11 years; open operation was performed and the epiphysis replaced. At the end of two years examination showed that the epiphysis had closed on the injured side while on the opposite side it still remained open. At the end of three years the uninjured epiphysis

48. Sever, J. W.: Fracture of Head and Neck of Radius, J. A. M. A. **84**:1551 (May 23) 1925.

49. Montgomery, A. H.: Arch. Surg. **10**:961 (May) 1925.

also had united to the shaft. At this time measurements showed that the injured radius was 1 cm. shorter than the uninjured one. The writer believes that with the same injury at an earlier age the interference with growth would be greater. The shortening would be likely to result in cubitus valgum with deflection of the olecranon to the medial side and possibly of compression of the ulnar nerve and late ulnar palsy.

Injuries of the Lower End of the Radius.—Zadek [50] has studied five cases of separation of the distal epiphysis of the radius and states that the condition usually remains unreduced when treated by the conventional methods used for Colles' fracture. A fracture of the lower end of the ulna above the styloid frequently accompanies the injury. In many cases in which the separation has remained unreduced nature has reconstructed the injured part so that ultimately there is no demonstrable difference between the two extremities. No growth interference occurred in any of the cases studied. Fixation of the wrist in the position of extreme palmar flexion (100 degrees) represents in the author's opinion a simple, direct, and mechanically efficient method of treatment. If the patient is not seen until some time after the injury there may be a posterior periosteal band of new bone which requires division before reduction can be obtained. This is done through a lateral incision just anterior to the attachment of the tendon of the brachioradialis into the base of the radial styloid.

Wrist Joint Injuries.—Carter [51] has made a study of 250 consecutive injuries in the region of the wrist joint, dividing them into two age groups, according to whether they were over or under 20, the age at which epiphyseal union should have taken place. As was to be expected greenstick fractures and epiphyseal separations occurred exclusively in the group under the age of 20. However, the most frequent injury in this group was a transverse fracture of both radius and ulna between 1 and 2 inches (2.5 and 5 cm.) above the wrist joint with backward displacement of both lower fragments. Above the age of 20 the most frequent form of injury was a transverse fracture of the radius within .1 inch, and most frequently about one-half inch (1.27 cm.) above the lower end with posterior displacement and impaction of the lower fragment, and in nearly half the cases associated with a fracture of the ulnar styloid. Injuries of the carpal bones are frequent complications.

Fractures of the Neck of the Femur.—Whitman,[52] writing on the treatment of fractures of the neck of the femur, states his opinion that the opposition to the abduction method of treatment is due to a reluc-

50. Zadek, Isadore: Arch. Surg. **10**:969 (May) 1925.
51. Carter, R. M.: Ann. Surg. **81**:532 (Feb.) 1925.
52. Whitman, R.: Ann. Surg. **81**:374 (Jan.) 1925.

tance on the part of the average surgeon to undertake the application of a secure and comfortable plaster spica. He feels that even in aged subjects it has been demonstrated that efficient treatment by the abduction method is actually more conservative than "life saving neglect." There are in his opinion two essential requirements for the proper application of the abduction treatment. The first is sufficient familiarity with the anatomic landmarks to verify the reduction of the fragments by manual traction and inward rotation, and to assure stability by the complete abduction of the limb to the normal limit on a level pelvis. The second essential is the ability to apply a secure and comfortable plaster support to hold the limb in the attitude that makes the internal splinting effective, namely, full extension, full abduction and slight inward rotation, the knee being somewhat flexed to relieve the strain, and the foot at a right angle with the leg, and slightly adducted.

Hesse [53] has made a histologic study of six specimens of fractured neck of the femur, and reports a noticeable difference in the vascularization of the head in different subjects. The ligamentum teres may contain rather large arterial vessels entering the spongiosa of the head, and these vessels may be of sufficient size to preserve considerable parts of the cortex and marrow and permit the regeneration of new bone. The amount of callus growing out from the marrow appears to bear a definite relation to the degree of vascularization. The mechanical displacement of the fragments and the interposition of the capsule seem to constitute the chief obstacles to bony union.

Lofberg [54] reports an analysis of 306 cases of fracture of the femoral neck treated at the Mälmo General Hospital during the period 1909 to 1922, and later examined in 1923. The treatment has consisted of bloodless reduction followed by fixation in abduction and inward rotation by means of a plaster-of-paris spica. From a study of the end-results the writer comes to the following conclusions:

1. The majority of nearly 62 per cent. of the cases of fracture of the neck of the femur have been medial fractures, the rest lateral.

2. One third of the cases have been males and two thirds females; 25 per cent. have been under 55 years of age.

3. With the reduction and plaster fixation method of treatment good osseous union has been obtained in 67 per cent. of the medial fractures and in 100 per cent. of the lateral fractures.

4. The fracture should be reduced as soon as possible unless general indications contraindicate.

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53. Hesse, F.: Arch. f. klin. Chir. **134**:141, 1925.

54. Lofberg, O.: Acta chir. Scandinav., Dec. 31, 1924, p. 504; abstr., J. A. M. A. **84**:790 (March 7) 1925.

5. In elderly people the reduction can generally be performed after an injection of morphin alone, or of scopolamin-morphin; sometimes of a little ether.

6. The medial fractures should be reduced and fixed in a position of internal rotation and abduction.

7. The torsion type of the lateral fractures should be reduced in internal rotation and abduction. The comminuted lateral fractures should be reduced in a degree of abduction suited to each separate case, but in other respects the leg should be in normal position. Lastly, the "crutch fractures" should be reduced in maximum abduction.

8. As a rule, fixation for a period of eight weeks seems to be sufficient; only in a few exceptional cases should it be extended over another two to four weeks.

9. After the plaster is removed the patient should remain in bed until he is able to lift his leg easily with the knee extended.

10. Weight bearing "with care" may then be permitted, a walking frame being used at first.

11. The critical period when there is the greatest risk of the fragments separating seems to be immediately following the removal of the plaster.

12. Passive movements should be prohibited, only active movements allowed.

13. Impacted medial fractures should be rebroken and reduced unless deformity is absent. In the latter case the hip should likewise be fixed in plaster.

14. Pseudarthrosis in young people in good general condition should be operated on if there is pain and considerable disturbance of function.

[ED. NOTE.—Lofberg's figures are impressive, particularly since they relate to such a large group of cases. The after-treatment is unorthodox according to the prevailing opinion in this country where twelve weeks represents the minimum time of fixation, and where protected weight bearing, usually with a caliper brace, is insisted on for a period of at least six months longer. The real problem of obtaining union centers in the medial type of fracture in patients beyond the age of 55. The lateral fractures present no problem and there is nothing surprising in a report of union in 100 per cent. of these cases. We do, however, find it difficult to reconcile the large percentage of union reported in the medial fractures with the short period of fixation and the early weight bearing which were used. It is probably fair to assume that union resulted in most of the patients under 55 years of age as they are the most favorable ones. Actually if we analyze the figures on this basis and make deduction for the 25 per cent. of patients below

the age of 55, it figures out that about 56 per cent. of the medial fractures beyond the age of 55 obtained union, or only a little over one half. In view of our own experience in which nonunion results all too frequently, even with treatment over a longer period, this figure would appear extremely gratifying. It is to be hoped that Lofberg's article will stimulate others to investigate end-results, and to report them with emphasis on the location of the fracture and the age of the patient.]

End-Result of Brackett's Operation for Ununited Fracture of the Neck of the Femur.—Brackett [55] reports an end-result in a case in which operation was done eight years before by the method he has devised for ununited fracture of the neck of the femur. The patient was a man, aged 53, whose fracture had been ununited for two and one-half years. At operation the hip was exposed, the upper part of the trochanter was cut off and the top of the shaft transplanted into the proximal fragment. A recent roentgenogram shows firm bony union, with normal appearing joint surfaces. This patient is steadily at work, does not use a cane, and has only a slight limp due to shortening, plus that accompanying a loss of hyperextension or possibly a few degrees of flexion of the hip joint. He does not experience any special tire with ordinary exercise, and can go up and downstairs with one foot after the other. The case is reported as of interest to demonstrate the possible functional condition of a joint following an operation for this injury after a long period of use. It emphasizes the fact that this operation should not be performed in cases that show an extensive degree of ostearthritic change or irregularity of cartilage outline, although decided porosity of the remaining head does not seem to be a contraindication for the operation. The advantage of the method is largely the fact that the normal joint structures are preserved in their normal relation.

Fracture of the Shaft of the Femur in Children.—Johnston [56] has compiled and studied thirty-two cases of fracture of the shaft of the femur in children. He urges that each case should be approached as a separate problem and that the choice of treatment should be governed by the character and location of the fracture and by the age of the patient. In children from 1 to 5 years of age, all types of fracture of the shaft of the femur, with the exception of those in the lower third, are best treated by Bryant's overhead extension. In children between the ages of 5 and 10 years, treatment of the fractures of the middle and upper thirds depends on the character of the fracture. If the

55. Brackett, E. G.: Boston M. & S. J., June 4, 1925, p. 1118.
56. Johnston, L. B.: Arch. Surg. **10**:730 (March) 1925.

fracture is transverse it is reduced and immobilized in the "mechano" splint, an adjustable type of Thomas splint for children.

The other method of treatment for transverse fractures in children between 5 and 10 years of age is reduction and fixation in the double spica cast. This is the most undesirable method and has given the poorest results. Its disadvantages are that the fragments often slip, that it is difficult to handle or make fluoroscopic examination of the limb, and that malposition, if it occurs, is not discovered for a week or more, when attempts at reduction are futile; the result is union with from 1 to 2 cm. of shortening.

Fractures of the lower third of the shaft of the femur in children of all ages, unless they are of such transverse character that the ends of the fragments can be approximated, constitute a separate problem. When treated in extension the lower fragment tends to be pulled backward by the gastrocnemius muscle. These fractures are treated by using the double plaster spica with the knee flexed to 45 degrees. In the writer's opinion this is the only type of simple fracture of the femoral shaft in which an open reduction would be justified and then only after an unsuccessful attempt by the closed method. In children more than 10 years of age the problem of managing a fracture of the shaft of the femur is comparable to that in adults.

[ED. NOTE.—This article is only another of many which concludes that the results in fractures of the femoral shaft in children are poorer following the reduction and plaster fixation method of treatment than after the use of the extension method. The only reason that the plaster method is still employed is because in the case of children nature is kind, and gross deformities with shortening are generally corrected in the course of time. We do not believe that this justifies us in lowering surgical standards, nor should we put too great a strain on nature. Though we may be content with less we should aim as high as in the adult cases. Treatment by extension in the Thomas splint is in our opinion the method of choice.]

Pseudarthrosis of the Tibia in Children.—Henderson [57] reports nineteen cases of pseudarthrosis of the tibia in children. He divides his cases into three groups: Group 1, congenital fractures; Group 2, fractures acquired in infancy or early childhood, and Group 3, fractures sustained in middle or late childhood. Operative treatment of Groups 1 and 2 by massive bone grafts resulted in failure in all cases. In Group 3, operation was performed in six cases with five cures; the one who failed to obtain union was operated on below the age of puberty. The author comes to the conclusion that the later in childhood the fracture is

57. Henderson, M. S.: J. Bone & Joint Surg., April 1925, p. 340.

sustained the better the prognosis following surgical intervention; further, that amputation is not justifiable, for if these children are carried beyond puberty by brace treatment their fractures become more amenable to surgery.

Operation for Unreduced Posterior Dislocation of the Elbow.—Speed [58] reports an operation he has worked out for unreduced posterior dislocation of the elbow. A median posterior incision is employed and the ulnar nerve identified and retracted. A V-shaped incision with its base at the olecranon is made through the triceps muscle, the tendinous portion being turned downward as a flap. The lateral and mesial portions of the condyles are freed by subperiosteal stripping of the muscles. A wide exposure is thus obtained with minimum damage to the joint structures. Callus and scar tissue are removed from the olecranon fossa, and reduction is then easily accomplished. In closing the incision the triceps muscle is reconstructed and sutured with chromic catgut. The after-treatment consists of fixation of the elbow in the right angle position from seven to ten days. Light massage and baking are then begun. By the end of the third week the splint is discarded and functional use of the arm encouraged. The results in a number of cases are reported to be gratifying.

Crucial Capsular Plication for Chronic Recurrent Dislocation of the Shoulder.—Keller [59] describes an operation he has employed with good results in chronic recurrent dislocation of the shoulder. The technic is as follows: An incision is made posterior to the axillary vessels over the humeral head where the posterior axillary fold fuses with the arm. The tendon of the latissimus dorsi is exposed and immediately above it the subscapularis muscle. The space between these structures is widened by blunt dissection and the capsule is exposed by retraction of the subscapularis muscle upward and inward. The circumflex nerve is isolated and the branches of the subscapularis vessels which pass backward through the space are retracted. At this stage it is necessary to free the capsule more completely by blunt dissection than is usually practiced in the ordinary capsulorrhaphy operation. The capsule is incised, midway between the glenoid and the humeral attachments and upward and downward as far as it is possible to reach. The open joint is explored for loose bodies which, if present, are removed. The arm is now elevated to the vertical position to relax the capsule and all sutures are introduced, but not tied. At this stage of the operation, the arm is carried close to the side of the head and all sutures are tied; and the crucial plication is completed

58. Speed, J. S.: Southern M. J. **18**:193 (March) 1925.

59. Keller, W. L.: Ann. Surg. **81**:143 (Jan.) 1925; abstr., J. A. M. A. **84**:848 (March 14) 1925.

while the arm is held in the position of greatest capsular relaxation and close to the angle at which dislocation most frequently occurs. A rubber tissue drain is carried down to the capsule and removed in twenty-four hours. The arm is bandaged to the side for three weeks and gradual upward motion is increased for two weeks more, and after this time the patient is allowed to proceed with all normal movements.

Nine patients have been operated on. One of the first patients was what might be termed loose jointed and the operation was a failure, but there has been no recurrence in the others. The crucial capsular plication advocated by the writer produces a crucial band at the point of greatest weakness in the capsule and uniform capsular contraction to a degree that is not possible when the old method of vertical plication alone is resorted to. The transverse part of the plication shortens the capsule and overcomes the dropping of the head in a large proportion of cases in which there is no impediment to its ascent. A great proportion of cases of habitual recurrent dislocation of the shoulder joint can be relieved by this simple operation on the capsule.

Amputations in Industrial Surgery.—Estes,[60] from a large experience, which embraces 727 cases, has contributed a valuable article on amputations in industrial surgery. The first problem that confronts the surgeon is to decide whether the general condition is such as to withstand an immediate operation. Hemorrhage must be checked and the circulating medium restored either by transfusion of blood or infusion of saline solution. Shock must be combated. The next question regards the nature and the severity of the injury to the limb and where to limit the "trimming process" so as to obtain a good useful stump. He considers that amputation is indicated in any of the following conditions: transverse crushes of all the anatomic elements of the limb; transverse lacerations of the limb if the blood supply is severed; transverse crushes such as are produced by a car wheel or the fall of a heavy steel beam, even though the skin may appear visible, if the bones and muscles are badly crushed.

Compound comminuted fractures in which as much as 3 inches (7.6 cm.) of bone has been lost and extensive laceration of the soft tissues about the bone has occurred should, as a rule, be amputated. Division of the chief blood vessels of a limb in a case of compound fracture usually requires amputation. If one is convinced, even though it may be possible to save the limb, that the conservative policy will leave a limb distorted and useless it is best to amputate. In the presence of gas bacillus or severe streptococcus infection amputation must be considered.

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60. Estes, W. L.: Ann. Surg. **81**:164 (Jan.) 1925; abstr., J. A. M. A. **84**:848 (March 14) 1925.

In the 727 cases of single major amputation, thirty-one patients died, a general mortality of 4.26 per cent. There were forty-six double synchronous amputations with three deaths, a mortality rate of 6.5 per cent. There were three triple synchronous amputations and no deaths. There were eighteen cases of "mixed" operations, that is in which some other operation of major importance was performed synchronously with the amputation, and here there were three deaths, or a mortality of 16.6 per cent. There were six cases of double amputation and some other major operation done at the same time with no deaths. There was one quadruple mixed operation; the patient recovered.

RESEARCH

Deposition of Calcium Salts.—Watt,[61] in a study of the deposition of calcium salts, says that:

1. Calcium phosphate and calcium carbonate show characteristic, easily identified shapes of particles when precipitated in colloids.

2. The bone salts are not present as discrete particles in bone and even in rapidly growing parts show no evidence of being deposited by simple precipitation.

3. Barille has shown that calcium salts are transported to the bone in the form of a complex double salt, calcium carbonophosphate. Evidence favors the view that the salts in bone are deposited by the activity of the osteoblasts, as a secretory function.

4. The direction of travel of the calcium salts can be reversed. They can be taken from the bone to raise the blood content when it is low. There is evidence of the presence of a calcium balance between bone matrix, osteoblasts and blood similar to the carbohydrate balance between glycogen, liver cell and blood.

5. In calcification the same salts are present as in ossification and in the same proportion. The difference is that osteoblasts are absent, and instead of bony matrix there is an area either of fibrosis or of necrosis.

6. There is evidence that calcification is a precipitation and in support of this view discrete characteristic particles of calcium carbonate have been seen in a calcified pineal gland as well as granules and irregular crystalline masses in calcified areas in the walls of arteries.

7. The presumption is that as its origin is by precipitation, a calcified area is permanent and neither will it disappear nor will it show rarefying changes such as may be seen in bone.

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61. Watt, J. C.: Arch. Surg. **10**:983 (May) 1925.

Separation of the Upper Femoral Epiphysis.—Mueller [62] has produced by experiment traumatic separation of the upper epiphysis of the femur. This leads to extensive necrosis or degeneration of the bone, whereas the articular cartilage may remain perfectly intact. The bone cells disappear and are replaced by a loose connective tissue containing many giant cells which arise from the epiphysis itself and not from the surrounding tissue. Hence, it is not a total necrosis. On the other hand, regeneration of the bone marrow and the bone tissue is not possible.

Dislocation of the head of the femur in children does not cause necrosis but atrophy. The same is true of the adult. In adolescence, with a fully developed head but still persisting epiphyseal line, separation of the epiphysis results in necrosis which takes place very rapidly. Regeneration in such cases depends on the amount of connection between the separated head and the living bone tissue. The regenerative transformation, as it is called by the author, takes places in a manner similar to that seen in arthritis deformans.

Aseptic necrosis is seen in traumatic separation of the epiphysis in coxa vara in the adolescent age, in Legg-Perthes' disease and in Koehler's disease of the second metatarsal head. It is interesting to note that in experimental necrosis compression fractures rarely take place, as is so frequently seen in Legg-Perthes' and in Koehler's disease. This may be explained by the greater resistance of the animal bone compared with that of children, especially in the age between 5 and 12 years.

[ED. NOTE.—These experiments are confused with clinical observations to a degree which makes the author's deductions inconclusive.]

Effects of External Heat Upon the Human Body.—In studying the effects of the application of external heat on the human body, Pemberton [63] has found that during the therapeutic application of external heat a loss of acid from the body occurs which results in a relatively increased alkalinity of the fluid tissues. This acid is mainly carbon dioxid and it makes its escape chiefly through the lungs although there is a considerable output through the urine and also through the sweat. Other acids also are eliminated and he has shown that in the sweat lactic acid is one of them, although the total amount is not great. The elimination of acids leaves an excess of alkali in the blood which then changes its reaction, becoming more alkaline. In the compensatory effort to meet this situation the excess of alkali is eliminated through the sweat and the urine. The profound nature of the changes induced by these measures is clearly indicated and explanation is afforded of some of the baneful consequences that follow their uncritical use. If carried to extremes tetany may result.

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62. Mueller, Walter: Beitr. z. klin. Chir. **132**:125, 1925.
63. Pemberton, Ralph: Am. J. M. Sc. **169**:485 (April) 1925.

MISCELLANEOUS

Roentgen-Ray Therapy of Thrombo-Angiitis Obliterans: Preliminary Report.—Philips and Tunick's [64] object in this paper is to report the results of roentgen-ray therapy in a series of fifty cases of circulatory disturbances of the extremities, most of which were thrombo-angiitis obliterans. The results in stimulative roentgen-ray therapy are attributable to increased activity of metabolic processes, particularly phagocytosis, and to biochemical changes similar to those produced in the establishment of immunity. The cause of thrombo-angiitis obliterans has not been definitely established. The disease occurs almost uniformly in males of the Semitic race. In their series all were males and Jews. Tobacco seemed undoubtedly a predisposing factor, either by producing alterations in the blood vessels directly and making them more susceptible to inflammation and thrombosis, or indirectly by effects on the vasomotor apparatus. All their patients were heavy tobacco users. There was pronounced improvement in the intermittent claudication within one or two weeks so that the patient could walk without distress for considerably longer distances. Improvement in the circulatory and trophic disturbances was noticeable in from one month to six weeks. There was a distinct change in the color of the extremity, the cyanosis or rubor improving. The results from roentgen-ray therapy in their series of cases are contrasted with the results of other forms of therapy. The uniformity of improvement in the circulatory disturbances and trophic changes, the relief of the most distressing and heretofore never completely relieved symptoms of pain, the low percentage of amputations, only 2 per cent., in their fifty cases, as compared with from 60 to 80 per cent. in the cases reported by others, seem to the authors to indicate the tremendous advantage which this method of treatment has over all other nonsurgical methods.

The Estimation of End-Results Following Injury.—Moorhead [65] advocates the adoption of an arbitrary standard for estimating end-results of fractures. This standard should be based on function, union and contour. Function is the essential end in view, union and contour subsidiary. Function refers to capacity to perform, union to state of repair, contour to external appearance. Each element is allotted a percentage value, the total of the three equaling 100 per cent.: function 60, union 20, and contour 20, equals 100 per cent., in other words, a perfect end-result. The author maintains that by adoption of such an arbitrary standard, the estimate of end-results will be both more accurate and more uniform.

(Concluded)

64. Philips, H. B., and Tunick, I. S.: J. A. M. A. **84**:1469 (May 16) 1925.
65. Moorhead, J. J.: J. Bone & Joint Surg. **7**:408 (April) 1925.

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